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Hurricane Hugo

Effects on South Carolina's Forest Resource

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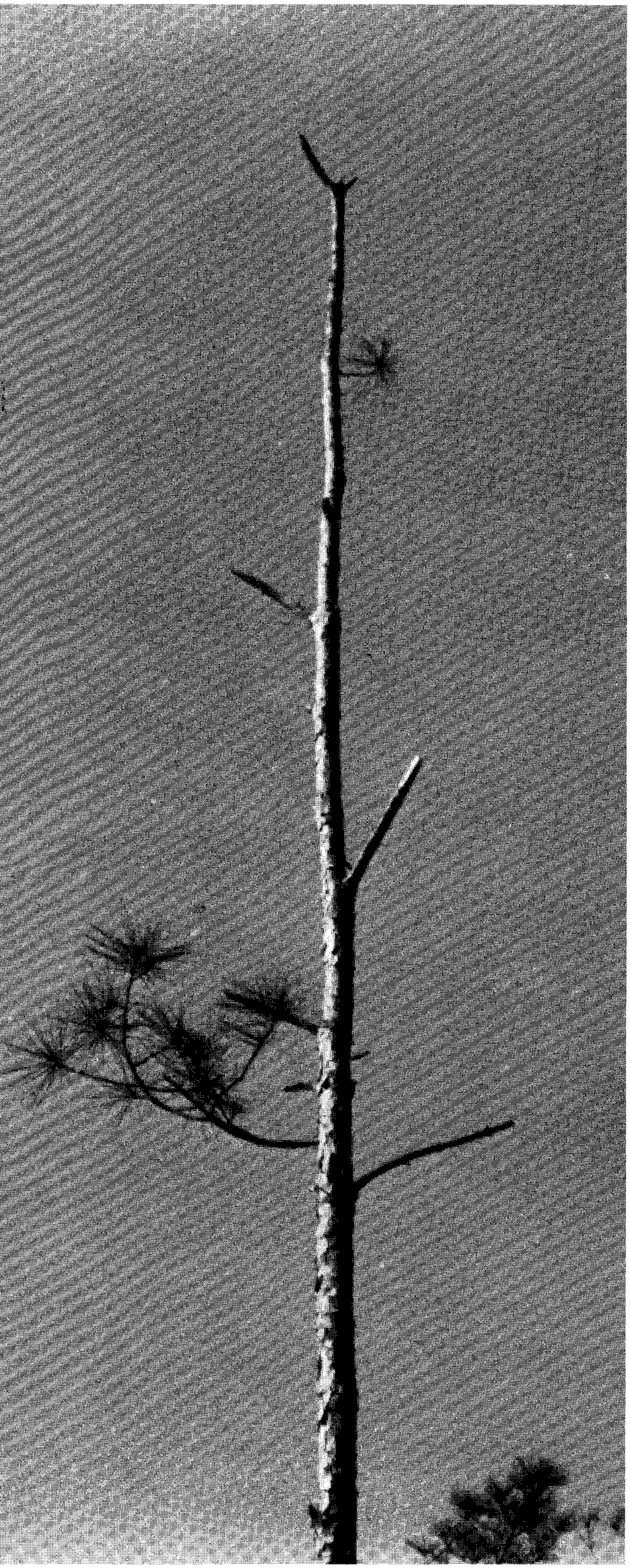

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Introduction

On September 21, 1989, Hurricane Hugo struck the coast of South Carolina near Charleston with sustained winds of 135 miles per hour. The storm moved northwest toward Rock Hill and exited the State with winds still at or near hurricane strength. Hugo has since been widely acknowledged as the greatest single forest disaster in the State's history.

Aerial and ground surveys conducted by the South Carolina Forestry Commission identified 23 counties with substantial forest damage. Damage estimates from this aerial survey guided the salvage of damaged timber, the establishment of fire control measures, and initial planning for reforestation. It was evident, however, that more comprehensive and objective data on the damage to the forest resource were needed to assess changes in wood supply, plan for necessary wood procurement shifts, and to guide long-term forest resource programs.

The Forestry Commission requested that the Forest Inventory and Analysis (FIA) Research Work Unit at the Southeastern Forest Experiment Station conduct a special inventory of the forest resource in the damaged area. The previous full-scale inventory of South Carolina was completed in 1986 (Tansey and Hutchins 1988). During the fall of 1989 and early 1990, objectives were established, field procedures developed, funds secured, and field crews assembled. The objectives of the inventory were to: (1) determine the volume of hurricane-related mortality and damage, (2) assess damage to merchantable and submerchantable pine plantations, and (3) quantify needed stand treatments resulting from the storm.

This report presents results, our interpretations, and documents the procedures used in the collection and analysis of the data.

Methods

Sampling Procedures

The sample plots used in the Hugo inventory included 2,530 permanent plots established in the 23 counties during the sixth survey of South Carolina in 1986 (fig. 1). FIA sample plots are based upon a 10-point cluster design. In most cases, five points are installed in a single forest condition using a basal area factor of 37.5 square feet per acre to sample trees 5.0 inches d.b.h. and larger. Trees less than 5.0 inches d.b.h. are tallied on 1/300-acre fixed plots at each of the point centers. More detailed information about standard FIA field sampling procedures is available (Tansey and Hutchins 1988; USDA Forest Service 1991). Between February 1990 and June 1990, each of the 2,530 ground samples was relocated and assessed for hurricane- and nonhurricane-related changes since 1986.

In accordance with the objectives, sampling procedures differed for natural and planted stands. In natural stands, field crews accounted for each tree that was 3.0 inches d.b.h. and larger in 1986. This procedure provided assurance that any tree that had grown large enough to have merchantable volume (5.0 inches d.b.h. and larger) would be evaluated. Each tree was assigned to one of six categories: (1) live, without hurricane damage; (2) live, with hurricane damage; (3) dead, hurricane related; (4) dead, not hurricane related; (5) cut, not associated with the salvage of damaged stands; or (6) cut, associated with hurricane salvage or cleanup operation, regardless of whether the tree was utilized for a product. Live trees with hurricane damage were assessed for volume loss, percentage of crown missing, lean and bend, root damage, degree of damage to the tree bole, and salt burn. Data-collection procedures are documented in more detail in appendix A.

In planted stands, data-collection procedures differed from those in natural stands in two respects: (1) field crews accounted for all trees that were 1.0-inch d.b.h. and larger in 1986; and (2) planted pine trees that had grown from less than 1.0 inch d.b.h. to greater than 1.0 inch and free-to-grow pine seedlings were tallied on 1/300-acre fixed plots around each of the point centers. These data were necessary to assess current stocking and damage levels in young plantations.

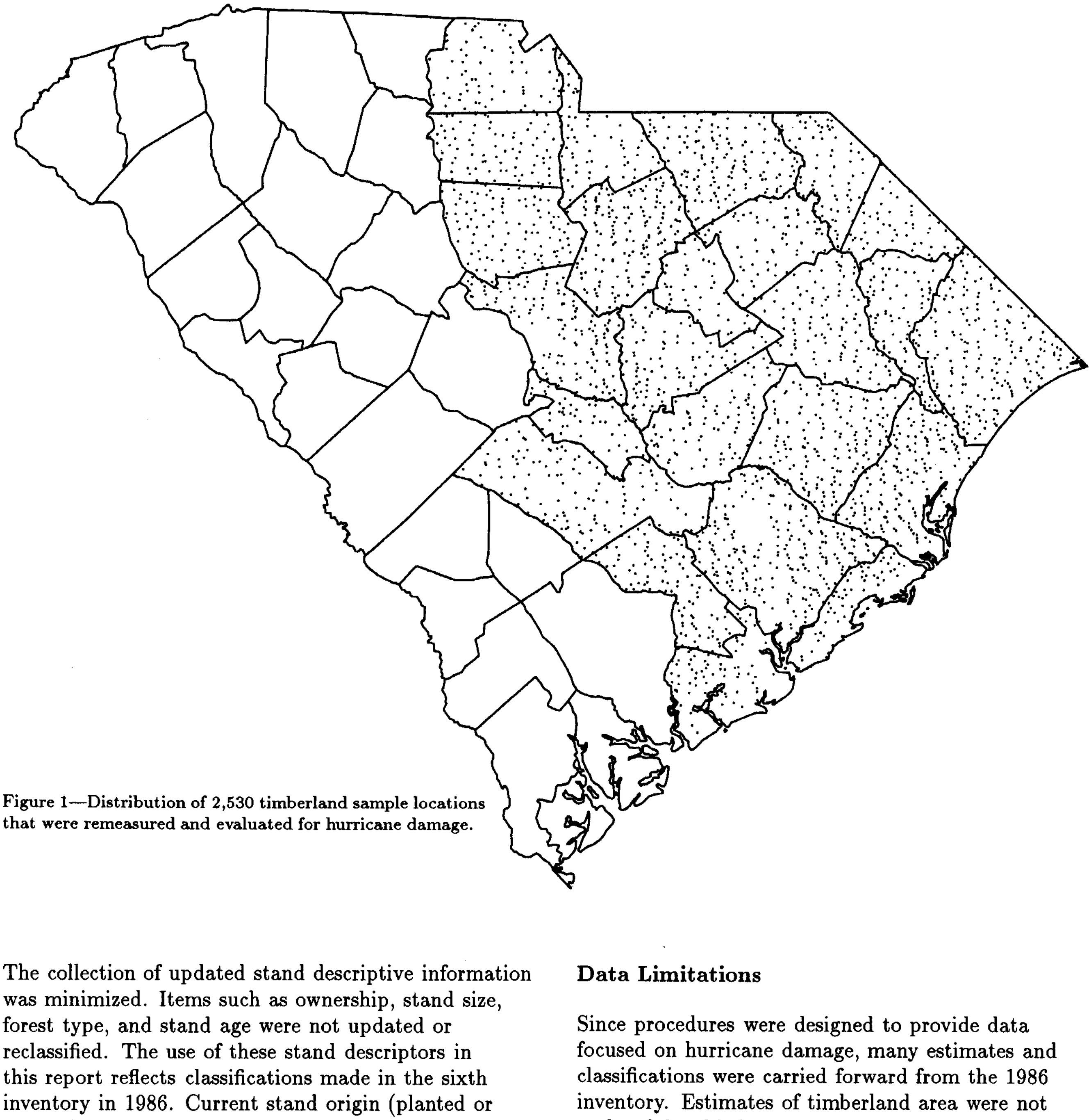

Figure 1—Distribution of 2,530 timberland sample locations that were remeasured and evaluated for hurricane damage.

The collection of updated stand descriptive information was minimized. Items such as ownership, stand size, forest type, and stand age were not updated or reclassified. The use of these stand descriptors in this report reflects classifications made in the sixth inventory in 1986. Current stand origin (planted or natural) was noted. Field crews also recorded the treatments and/or disturbances, including hurricane damage, that had occurred in each stand since 1986. Finally, crews assessed treatment opportunities at each plot—salvage cuts, regeneration, thinning, etc.—along with the potential for natural pine regeneration.

Data Limitations

Since procedures were designed to provide data focused on hurricane damage, many estimates and classifications were carried forward from the 1986 inventory. Estimates of timberland area were not updated for this inventory; thus, no change in timberland area is factored into the volume change estimates. Forest type, ownership, stand size, and age were not reestimated. The reader should be aware that tables displaying these stand and area descriptors may differ somewhat from true conditions in 1990. For example, major land transactions since 1986 that would affect the acreage by ownership are not reflected in tables or illustrations in this report. All displays of age class or stand type portray 1986 conditions prior to any cutting, treatment, or hurricane disturbance. An exception was made when planting was noted on a plot. Then, the broad stand type was changed to pine plantation and a zero (0) age class was assigned.

A complete assessment of current stocking and hurricane damage in very young natural stands was hampered because no trees less than 3.0 inches d.b.h. were measured or sampled there in 1990. Field crews did assess treatment opportunities in these stands, reflecting the degree of damage inflicted.

Finally, the Hurricane Hugo inventory is limited to providing updated volume statistics for the 23 counties identified as sustaining significant damage. Volume estimates for the entire State cannot be estimated directly from these data.

Classification of Live-Tree Damages

The inventory procedures were designed to estimate inventory change in the selected counties and to meaningfully describe damage to the existing inventory. The new inventory includes all merchantable trees that were alive at the time field crews visited each ground location. All types of significant damage to sample trees were recorded to best describe the condition of each tree. A logical classification system was needed to accurately assess and illustrate the true extent of damage, but no suitable one was known to exist. The challenge was to place each tree into a meaningful category that would provide a reasonable description of damage severity and risk of dying in the near future. Draft criteria were developed for different categories of tree size, species group, and stand type to place each tree in the appropriate class of damage. The criteria were submitted to 20 individuals or organizations for review. Review comments were received from 13 individuals or organizations, and final criteria were developed. These criteria and a description of evaluation methodology are in appendix B.

The damage/risk classes were designed to reflect the likelihood of tree survival and present (or potential) value degrade. The categories are:

Class 1—High-risk tree with a high probability of dying in the near future. Damage and value loss are severe enough that this tree should not be retained in the stand.

Class 2—Moderate-risk tree with elevated risk of mortality; serious current or potential loss of value; retention in the stand is questionable.

Class 3—Low-risk tree that has a high probability of surviving, though not as high as an undamaged tree. Damage and value degrade are minimal—these trees should be retained in the stand in most management scenarios.

Healthy—No obvious hurricane damage. A tree with hidden or internal damage would be included here.

The damage/risk evaluation process placed trees into discrete categories. We recognize that, in reality, damaged trees belong on a continuum ranging from "not damaged" to "nearly dead." Our process was uncomfortably subjective. We found only a limited number of research studies for guidance (Barry and others 1982; Brewer and Linnartz 1973). We defend it primarily on the basis that it seems practical. We hope that our detailed description of methods will help in understanding Hugo damage and will lead to improvements in damage estimation techniques in the future.

Affected Area and Volume

This chapter summarizes our estimates of the amount and location of timberland that was significantly affected by Hurricane Hugo. It also provides estimates of the losses of softwood and hardwood timber volumes. Additional data on damage are in appendix C.

More Than 4.5 Million Acres Damaged

The reinventory indicates that 4.5 million acres, or two-thirds of the 6.5 million acres of timberland in the 23 counties, were damaged by Hurricane Hugo (app. table C.21). About 37 percent of South Carolina's timberland sustained some storm damage.

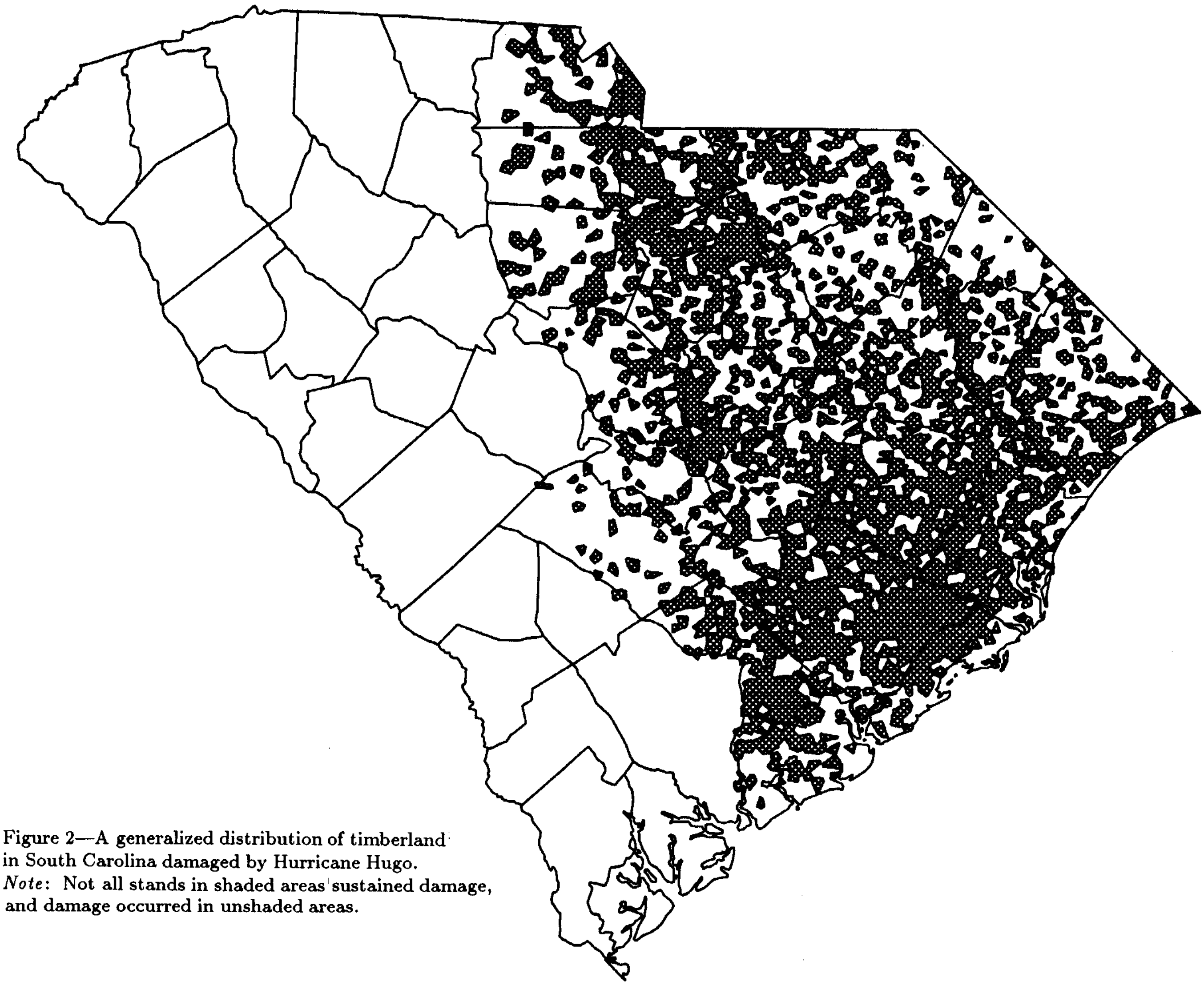

Figure 2—A generalized distribution of timberland in South Carolina damaged by Hurricane Hugo.
Note: Not all stands in shaded areas sustained damage, and damage occurred in unshaded areas.

Timberland damage was most widespread near the coast and on the northeast side of the hurricane's eye as it moved in a northwesterly direction. Figure 2 shows the generalized distribution and extent of hurricane damage in South Carolina. One should not conclude, however, that all stands in the area shown as damaged sustained damage or that damage does not exist in the unshaded areas. Representations of damaged timberland were created by drawing Thiessen polygons (Newton and Bower 1990) around each ground location classed as having hurricane damage. Adjacent polygons depicting damage were merged into a single polygon by deleting interior polygon lines. Undamaged timberland and nonforest plot locations are portrayed as undamaged on the map. Therefore, the higher incidence of nonforest land in the central portion of the State lends an appearance of less damage there than in the lower coastal plain or in the more heavily forested areas to the north.

Hurricane Hugo damaged more than 90 percent of the timberland in six counties—Berkeley, Clarendon, Florence, Lee, Sumter, and Williamsburg. The distribution of damage suggests that there probably was damage in some counties not reinventoried, most notably Colleton and Lexington Counties. The damage in these counties was acknowledged prior to the field work; they were omitted because of the limited extent of damage and increased data-collection effort required.

Substantial hurricane damage was found in all stand types and broad management types (app. table C.21). Sixty-two percent of the pine plantation acreage was affected, compared with 68 percent for natural pine and oak–pine stands, and 64 percent for upland hardwood stands. Lowland hardwood stands sustained the highest incidence of damage—77 percent. Lowland hardwood stands often contain large, shallow-rooted trees with large crowns, factors associated with increased susceptibility to wind damage (Barry and others 1982; Hook and others 1991). Across all stand types, the damage incidence rate averaged 76 percent for stands classified as sawtimber size, 67 percent for poletimber, and 59 percent for sapling–seedling.

Timberland in public ownership was the most severely affected in terms of acres damaged—79 percent of the acreage controlled by public agencies sustained some hurricane damage (app. table C.21). One factor contributing to the high incidence is the large concentration of National Forest in the most severely affected area near the coast in Berkeley and Charleston Counties. Another reason for the high rate of damage on public land is that the older stands and larger trees characteristic of public forests are more susceptible to wind damage. Tall, large-diameter trees sustained more damage than smaller trees. Forest industry land and nonindustrial private forest (NIPF) land were both equally affected by the hurricane; 68 percent of the acreage in these two classes was affected.

Softwood Inventory Reduced by 21 Percent

Hurricane Hugo reduced the inventory of softwood growing stock by 21 percent, from an estimated 4.8 billion cubic feet that existed prior to the storm to 3.8 billion cubic feet (fig. 3 and app. table C.1). Some 376 million cubic feet of Hugo-damaged softwoods were salvaged, and 632 million cubic feet were killed but not salvaged. The extent and nature of damages to trees

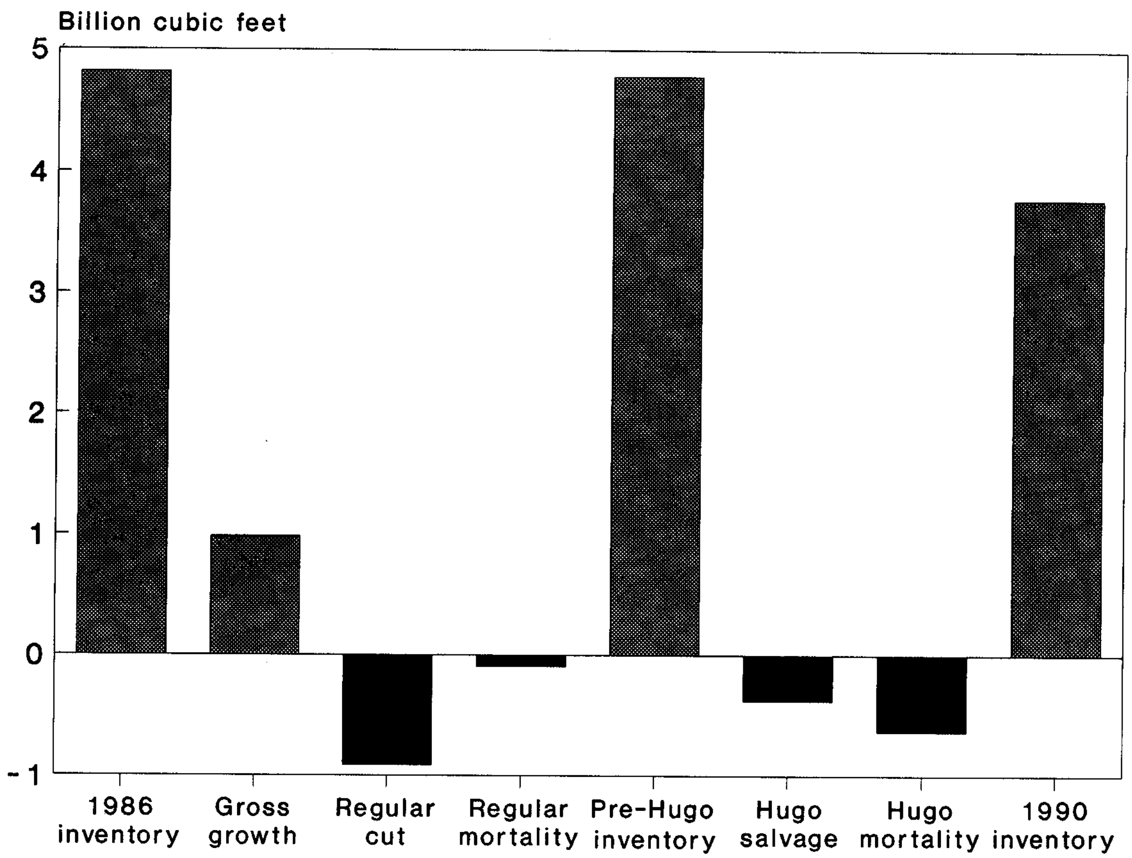

Figure 3—Change in volume of softwood growing stock, by component of change.

that were not killed will be discussed later. Softwood sawtimber volume declined from an estimated 19 billion board feet to 14 billion board feet, a drop of more than 25 percent (app. table C.3).

Not all the volume classed as salvage was utilized for wood products. Our total includes all damaged trees that were cut after the hurricane. Some of these trees were cut in cleanup operations in which the stems were not utilized, and some were cut but not utilized during salvage operations. The South Carolina Governor's Forest Disaster Salvage Council tracked actual salvage volumes removed for product use and can provide final statistics.

The pre-Hugo estimate of softwood inventory was developed by adding estimates of gross growth (1 billion cubic feet) to the 4.8 billion cubic feet present in 1986 and subtracting non-Hugo-related softwood removals (900 million cubic feet) and mortality (100 million cubic feet). We are fairly certain that softwood volume changed little from 1986 until Hugo struck, but we acknowledge that errors are associated with the computation. For instance, field crews encountered some difficulty in determining whether a tree was cut prior to the hurricane or whether it was removed during a storm-related salvage operation. Also, some growth occurred between the time Hugo struck and the date of plot measurement the next spring; this volume increment was assumed to be minimal. In establishing the pre-Hugo inventory, all growth was assigned to the period before the storm's occurrence. To more accurately describe storm impacts in the text, all losses and changes are related to the pre-Hugo inventory rather than the 1986 inventory. This rule is not strictly adhered to in the appendix tables, but the values reported and their bases for change are well defined in the tables.

Declines in softwood inventory were recorded in all 23 counties, but declines were greatest in counties near the coast and along the path of the hurricane's eye (fig. 4). More moderate losses occurred in counties more distant from the path. Six counties—Berkeley (49 percent), Charleston (47 percent), Clarendon (45 percent), Sumter (44 percent), Lancaster (35 percent), and Lee (34 percent)—lost more than one-third of their pre-Hugo softwood inventory. Berkeley and Charleston Counties alone accounted for 43 percent of the Hugo-related drop in softwood inventory.

Declines in softwood inventory varied considerably among the major ownership categories (app. tables C.7 and C.9). The most severe loss occurred on land controlled by public agencies. Volume of softwood growing stock fell 34 percent to 451 million cubic feet on public land. Public land, which accounted for only 14 percent of the pre-Hugo softwood inventory, sustained 23 percent of the softwood volume loss. More than one-third of the total softwood mortality caused by the hurricane occurred on publicly owned timberland—about 204 million cubic feet. The location of National Forest land in the storm's path and the larger-than-average size of trees on this land explain the heavy losses sustained there. The volume of softwood growing stock dropped by only 12 percent to 907 million cubic feet on timberland controlled by forest industry. The percentage reduction was smallest for this owner category. In this region a high proportion of forest industry holdings are in young pine plantations. Of the 1.6 million acres of forest industry timberland, about a fourth was in planted pine stands under 20 years old in 1986. The small trees in the planted stands sustained considerably less damage and mortality than larger trees in older stands. Hugo-related salvage also was relatively small on industry land. Forest industry land supplied only 11 percent of all Hugo-related softwood growing-stock removals. Softwood inventory held by NIPF owners was reduced by 21 percent from 3.1 to 2.4 billion cubic feet.

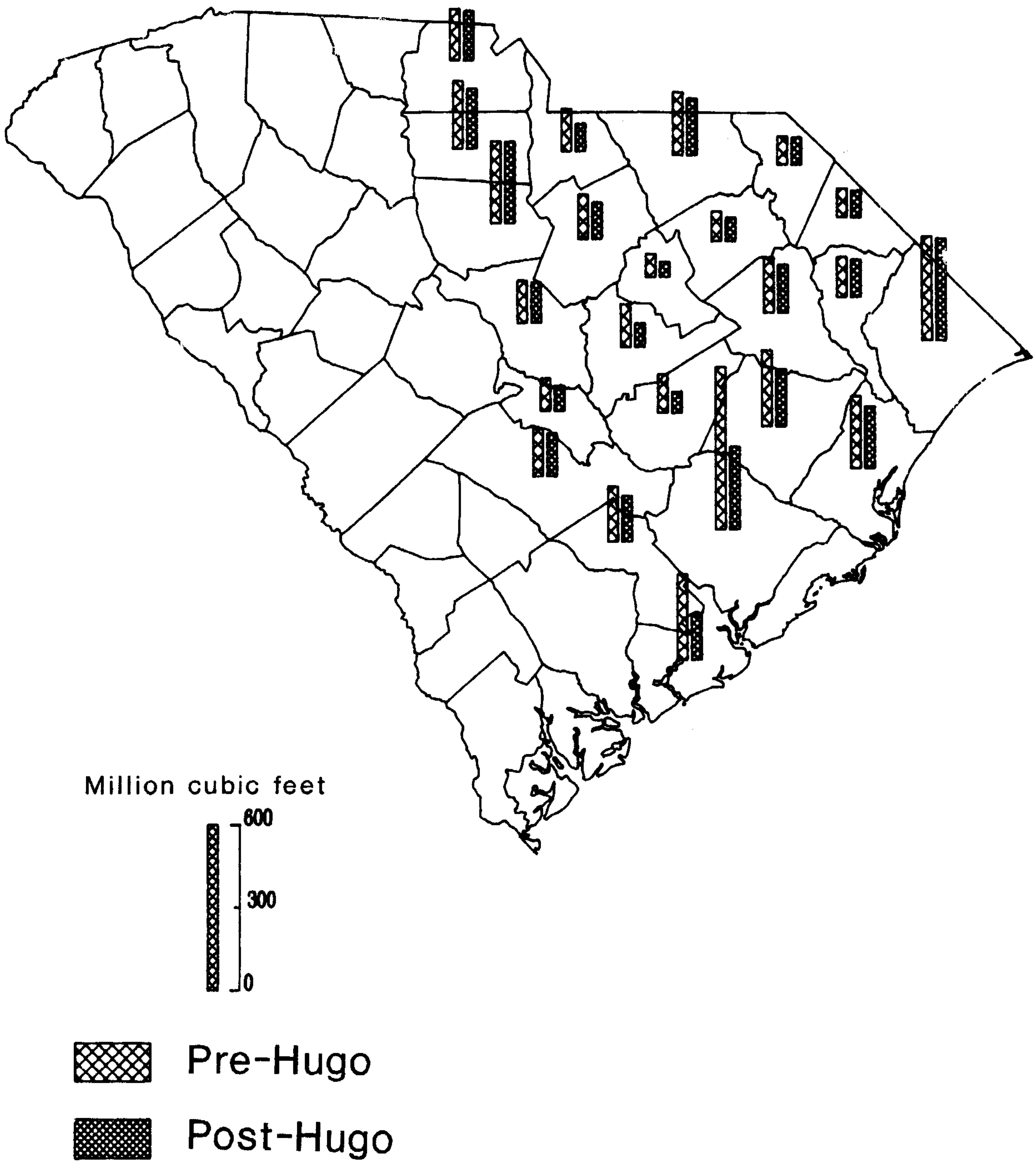

Figure 4—Pre- and post-Hugo softwood growing-stock inventories, by county.

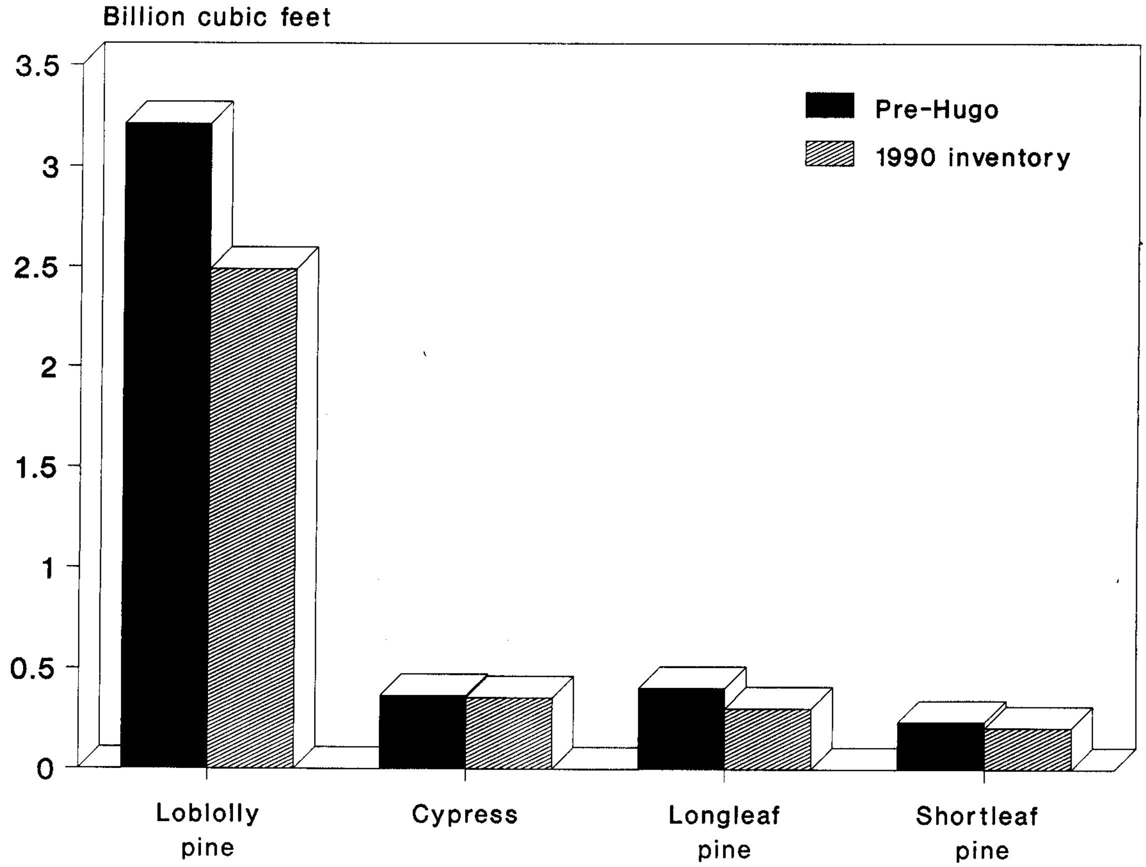

Figure 5—Pre- and post-Hugo softwood growing-stock inventories, by species.

No yellow pine species was especially resistant to the hurricane's winds (fig. 5 and app. tables C.17 and C.19). Loblolly pine inventory fell by 22 percent in the wake of Hugo to 2.5 billion cubic feet. By far the most abundant species in the region, loblolly pine accounted for 72 percent of the decline in softwood inventory. Volume of longleaf pine fell by 25 percent to 303 million cubic feet. Slash and pond pine volumes declined by 27 and 29 percent to 146 and 180 million cubic feet, respectively. Shortleaf pine experienced a smaller decline of 13 percent to 205 million cubic feet. However, shortleaf occurrence is concentrated in the areas away from the coast.

Cypress survived the hurricane surprisingly well. The inventory of cypress fell by only 3 percent to 355 million cubic feet. Putz and Sharitz (1991) also found that cypress was able to withstand the hurricane's winds better than most species in the Congaree Swamp.

Softwood volume declined across the entire range of diameter classes (fig. 6 and app. tables C.13 and C.15). Volume declined by 8 percent in the 6-inch class, by 11 percent in the 8-inch class, and by 16 percent in the 10-inch class. Reductions ranging from 22 to 32 percent were recorded in the larger diameter classes. The high losses in the larger size classes show that large pines were particularly susceptible to bole breakage, windthrow, and subsequent mortality.

Further Softwood Mortality Losses Likely

Observations of damaged trees not killed by the storm suggest that substantial additional softwood mortality is likely in the next few years. Of the 3.8 billion cubic feet of softwood growing stock classified as live timber (post-Hugo inventory), 29 percent, or nearly 1.1 billion cubic feet, was damaged to some extent (app. table C.5). Almost half of this damaged volume was in the lowest risk category—class 3. However, nearly 0.6 billion cubic feet was in trees classed as moderate or high risk. No attempt will be made here to estimate the additional mortality that is likely to occur. The rate of loss will depend on factors such as weather, insects, disease, and further salvage efforts. However, the potential for additional mortality of several hundred thousand cubic feet is present.

As with mortality, damage to live trees was greatest on public forests (app. tables C.11 and C.12). More than 36 percent of the 1990 softwood inventory on

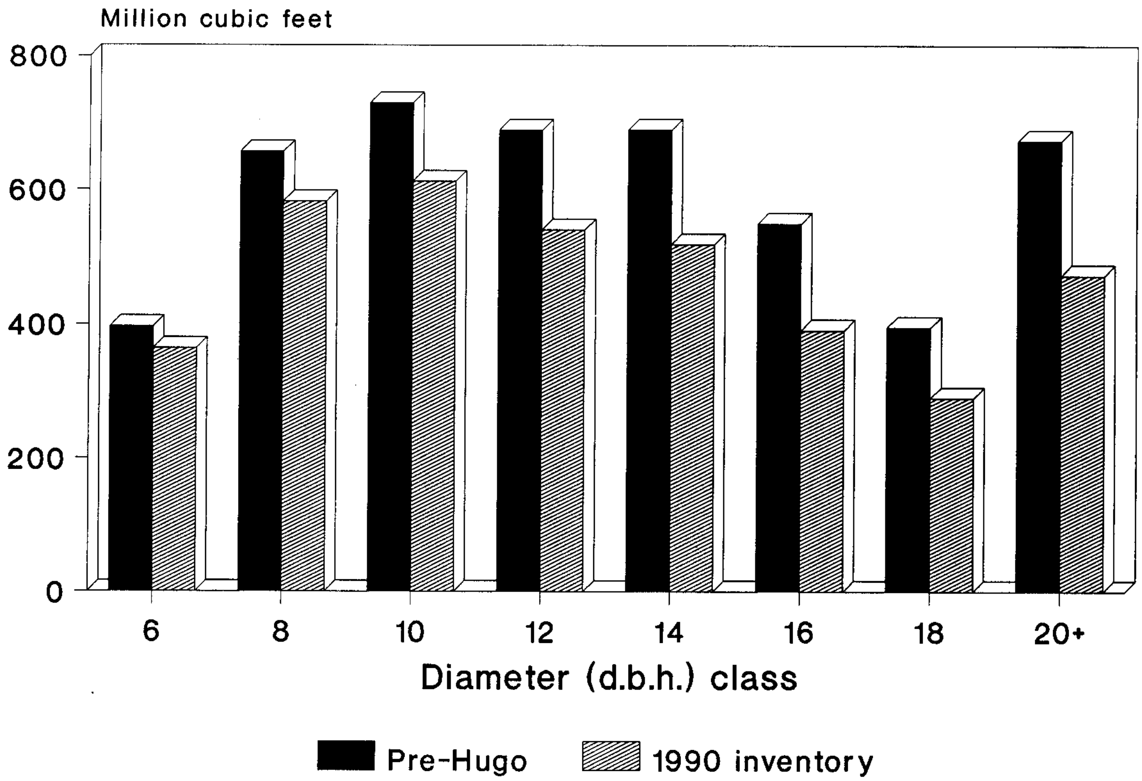

Figure 6—Pre- and post-Hugo softwood growing-stock inventories, by diameter class.

public land was damaged to some degree with severe and moderate damage (classes 1 and 2) present on 22 percent of the post-Hugo softwood inventory. About 36 percent of the post-Hugo softwood inventory on forest industry forests was damaged, but 19 percent was in the class 3 or low-risk group. Some 26 percent of the post-Hugo softwood volume on NIPF land was damaged; 6 percent was in the class 1 category, 8 percent in class 2, and 12 percent in class 3.

Softwood Damage Summary

Damage to softwood growing-stock (using the pre-Hugo inventory as a base) is summarized in figure 7. About 8 percent of the pre-Hugo inventory was removed in salvage operations, and another 13 percent (0.6 billion cubic feet) was dead at the time of plot remeasurement. Hugo-related mortality will continue to accumulate for a number of years. Some 23 percent

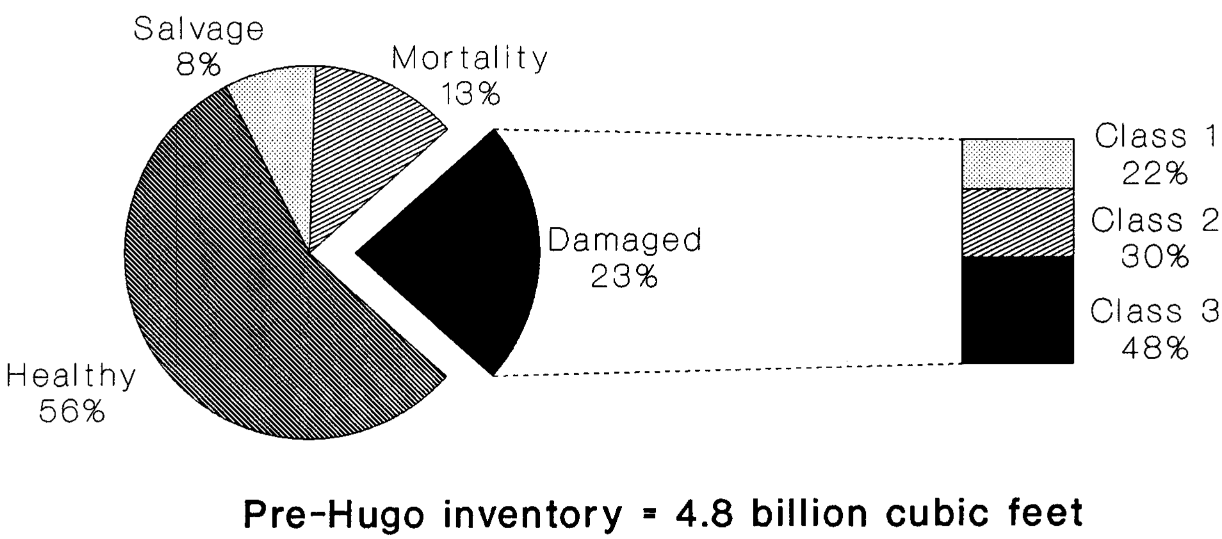

Figure 7—Summary of hurricane losses and damage to the pre-Hugo softwood inventory.

of the softwood inventory before Hugo is in damaged living trees. About 2.7 billion cubic feet, or only 56 percent of the pre-Hugo inventory, was classed as "healthy," or having no obvious storm-related damage. Thus, softwood inventory losses to Hurricane Hugo range somewhere between the 21 percent (1.0 billion cubic feet) killed directly or salvaged immediately after the storm and the 44 percent (2.1 billion cubic feet) killed, salvaged, or damaged. A reasonable estimate of softwood loss is around 30 percent of pre-Hugo inventory (1.4 billion cubic feet).

Hardwood Inventory Reduced by 6 Percent

Hurricane Hugo reduced the inventory of hardwood growing stock in the 23 counties by 6 percent to 4.8 billion cubic feet (fig. 8 and app. table C.2). Sawtimber losses were similar in magnitude (app. table C.4). An estimated 5.1 billion cubic feet of hardwood growing stock was present prior to Hugo, up from 5.0 billion cubic feet in 1986. Hardwood inventory reductions were attributed to 270 million cubic feet of Hugo-related mortality and to only 49 million cubic feet of salvage. These losses are small in comparison with softwood losses for two reasons. First, there was little hardwood salvage cutting—most of the efforts to salvage dead and damaged timber focused on pine species. Second, softwood species died more quickly after windthrow, bole breakage, or loss of limbs, whereas hardwood species were generally still alive. Even windthrown hardwoods and those that lost their entire crown were sprouting new growth the spring after the storm. Many of these severely damaged hardwoods will die, and the wood in those that do not will be degraded badly.

Geographically, the distribution of hardwood volume loss followed essentially the same pattern as for softwoods (fig. 9). The counties with the most severe

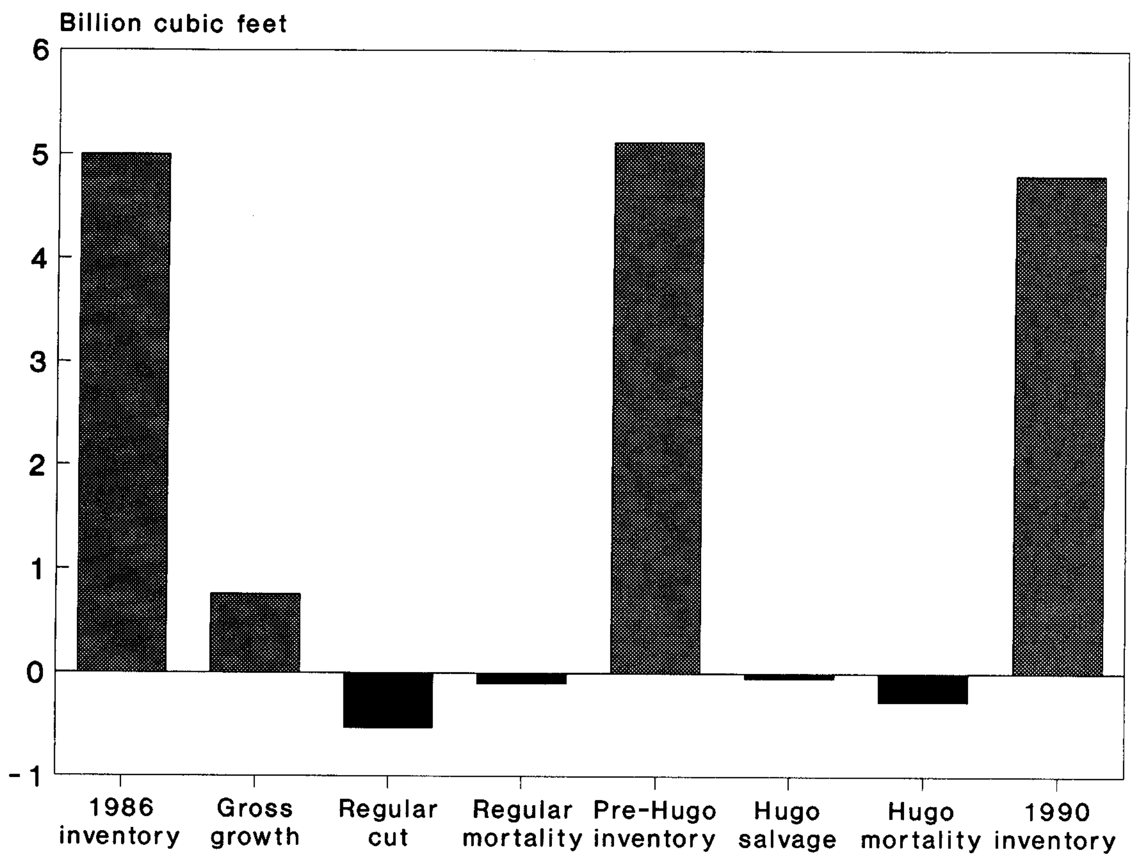

Figure 8—Change in volume of hardwood growing stock, by component of change.

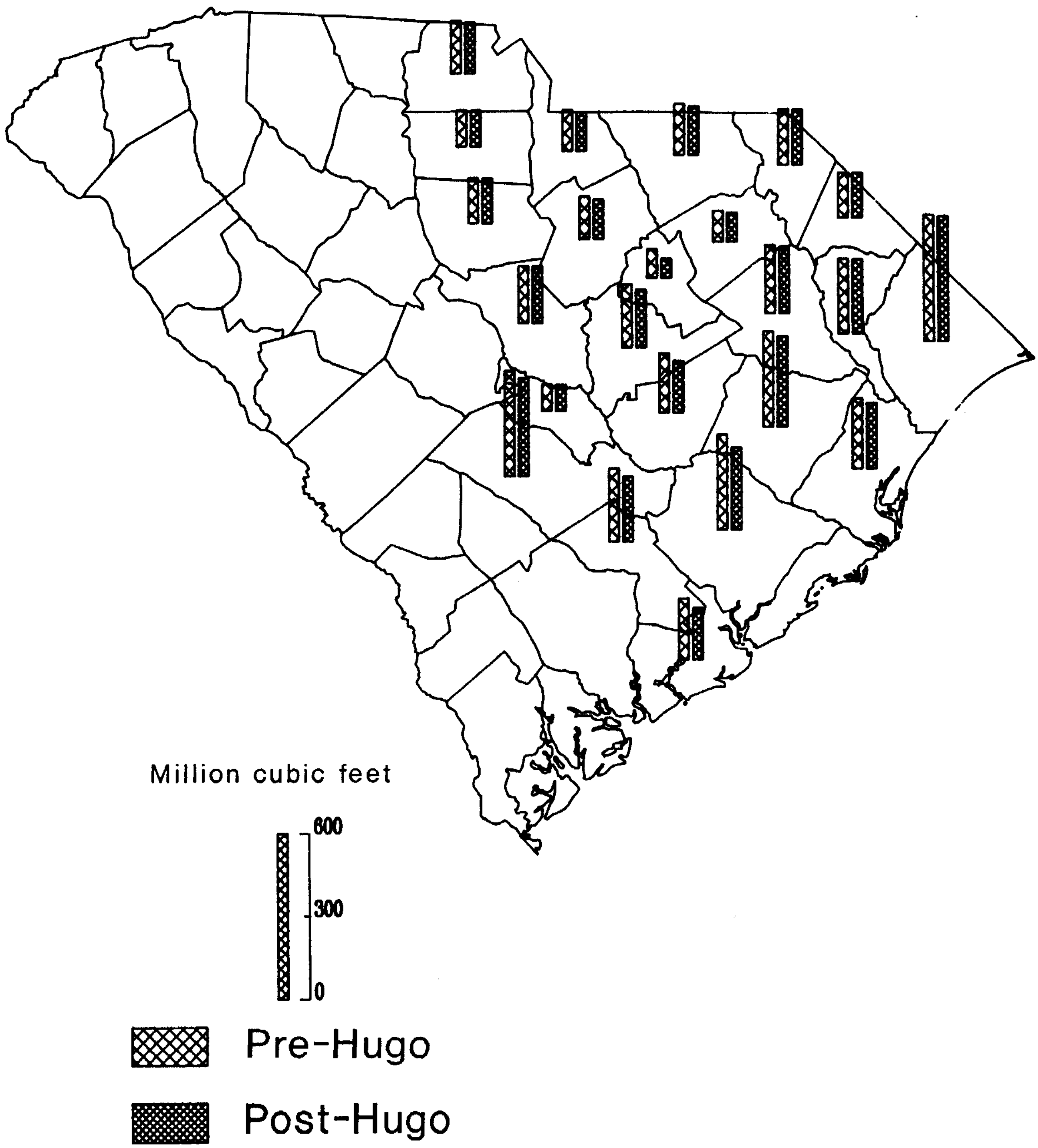

Figure 9—Pre- and post-Hugo hardwood growing-stock inventories, by county.

declines in hardwood volume are near the coast and along the path of the hurricane's eye. Lee County lost 34 percent of its hardwood inventory, whereas Charleston lost 16 percent, and Berkeley 14 percent. Among ownership classes, public land sustained the most severe reductions in hardwood volume (app. tables C.8 and C.10). The hardwood inventory controlled by public owners declined by 16 percent to 237 million cubic feet. That controlled by forest industry decreased by 5 percent from less than 1.1 to about 1.0 billion cubic feet. Hardwood inventory on NIPF land dropped 6 percent from 3.8 to 3.6 billion cubic feet—near the average for all ownership categories.

Large hardwoods were the most prone to hurricane-related mortality (fig. 10 and app. tables C.14 and C.16). The inventory of hardwoods 20 inches d.b.h. and larger dropped by 9 percent, whereas reductions were more modest for smaller trees.

Volumes of all major hardwood species in the region decreased (fig. 11 and app. tables C.18 and C.20). Red oaks suffered the most severe drop of 10 percent to 1.0 billion cubic feet. The sweetgum inventory declined by 6 percent to 1.0 billion cubic feet. Volume of tupelo and blackgum—the predominant hardwood species group in the region—dropped 3 percent to 1.1 billion cubic feet. Volume of all white oaks dropped 7 percent to 420 million cubic feet. The small loss of blackgum and tupelo relative to other hardwoods is consistent with findings of a study in the Congaree Swamp (Putz and Sharitz 1991).

Very Heavy Hardwood Damage

Severely damaged hardwoods did not die as quickly after the storm as did softwoods. As a result, hardwood mortality understates the real terrible blow to the hardwood resource. That blow is expressed primarily in the figures for damaged, living trees.

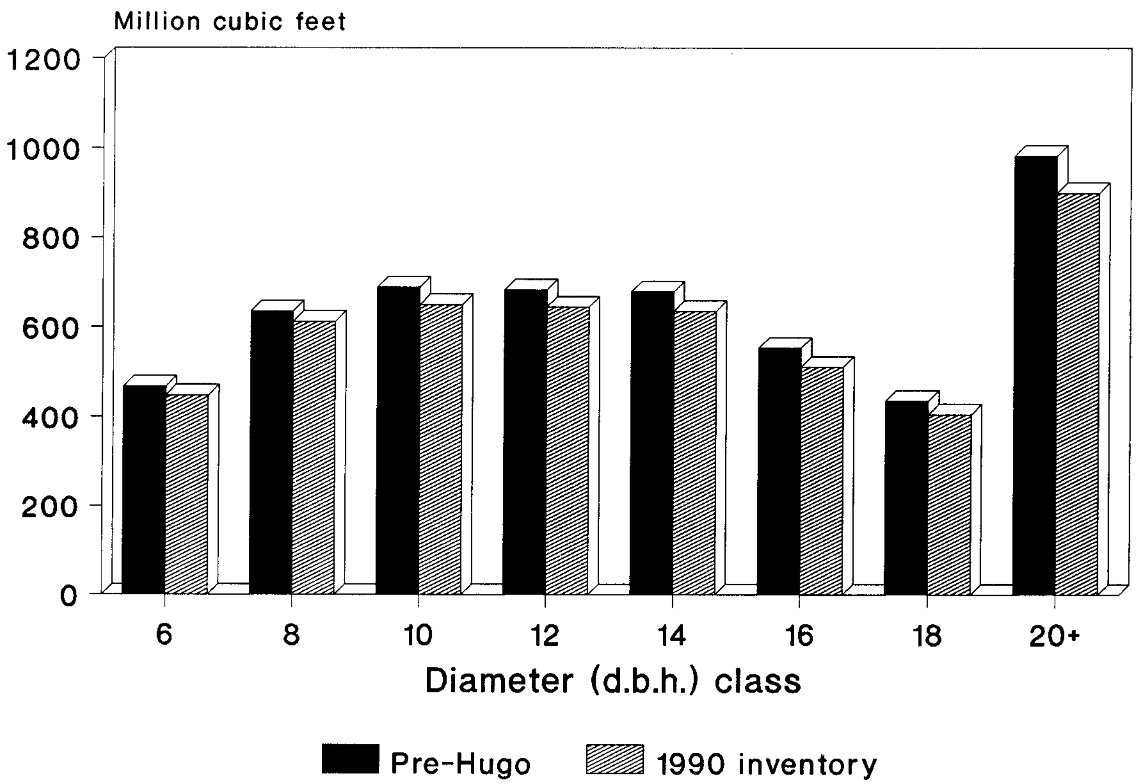

Figure 10—Pre- and post-Hugo hardwood growing-stock inventories, by diameter class.

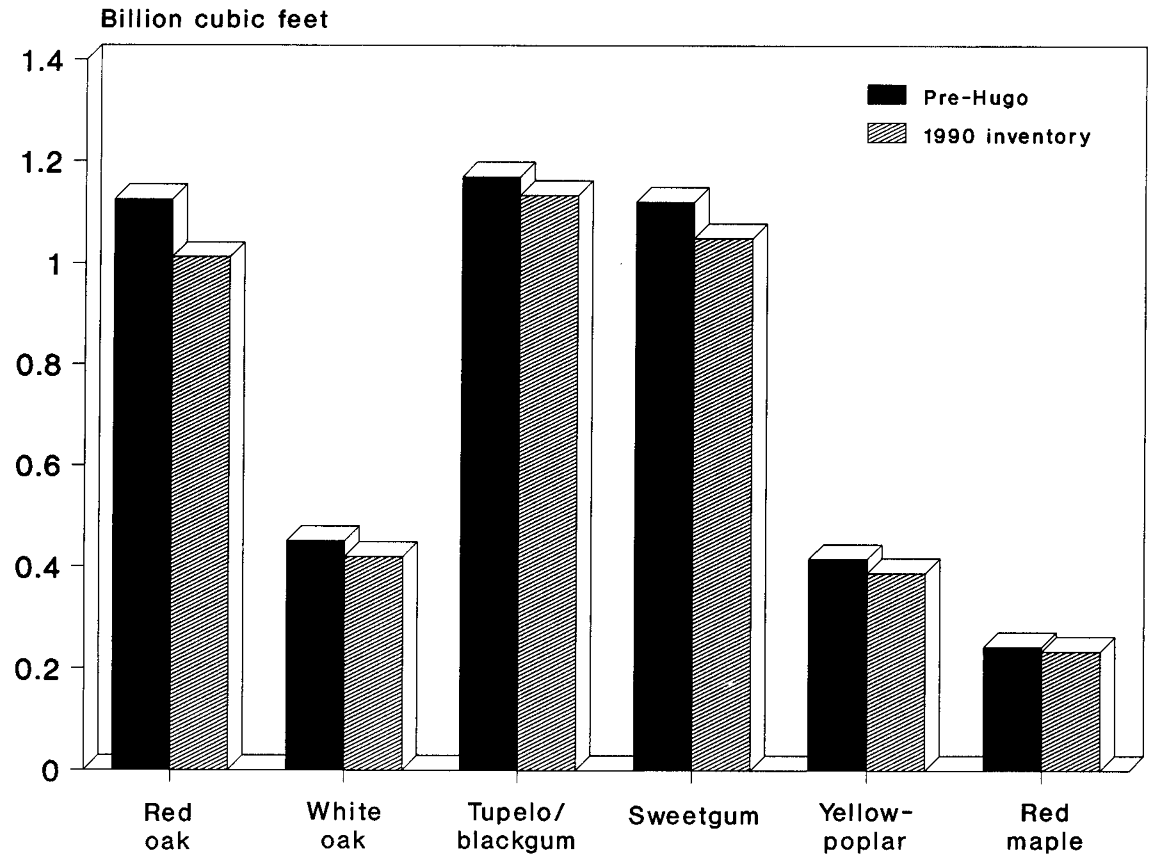

Figure 11—Pre- and post-Hugo hardwood growing-stock inventories, by species.

Thirty-two percent of the post-Hugo hardwood inventory is damaged to some degree (app. table C.5). Damaged trees contain 5.3 billion board feet of hardwood sawtimber. About 12 percent of the 1990 hardwood growing stock is in high-risk trees. Only 6 percent of the softwood inventory is in this class. Eight percent of the hardwood volume is in class 2 trees and 12 percent is in class 3 trees.

Public lands contained the highest proportion of damaged hardwood volume—51 percent of the post-Hugo hardwood inventory on public forests was damaged to some degree (app. tables C.11 and C.12). National Forests were most severely damaged; 60 percent of the 1990 hardwood inventory was damaged, and two-thirds of the damaged volume is in trees in classes 1 and 2. On both forest industry and NIPF land, about 31 percent of the 1990 hardwood inventory was damaged after the storm.

High-risk (class 1) trees are more prevalent with increasing diameter for hardwoods (app. table C.14). Less than 10 percent of the volume in hardwood trees 15.0 inches d.b.h. and smaller was classified as high risk. For hardwoods larger than 15.0 inches, the proportion in class 1 averaged 18 percent, and it exceeded 21 percent for the largest trees. The proportions of damaged hardwoods in classes 2 and 3 did not change substantially across the range of diameter classes.

Red oaks appear to have suffered the most (app. table C.18). About 42 percent of the 1990 red oak inventory was damaged, and one-half of the affected trees was in class 1. Some 31 percent of white oak volume was affected, and 14 percent was in class 1 trees. In contrast, only about 22 percent of the tupelo and blackgum volume was damaged and most of this volume was in class 3 trees. About 304 million cubic feet, or 29 percent, of the sweetgum volume was damaged; 40 percent of yellow-poplar volume was damaged; and 42 percent of the soft maple volume was damaged.

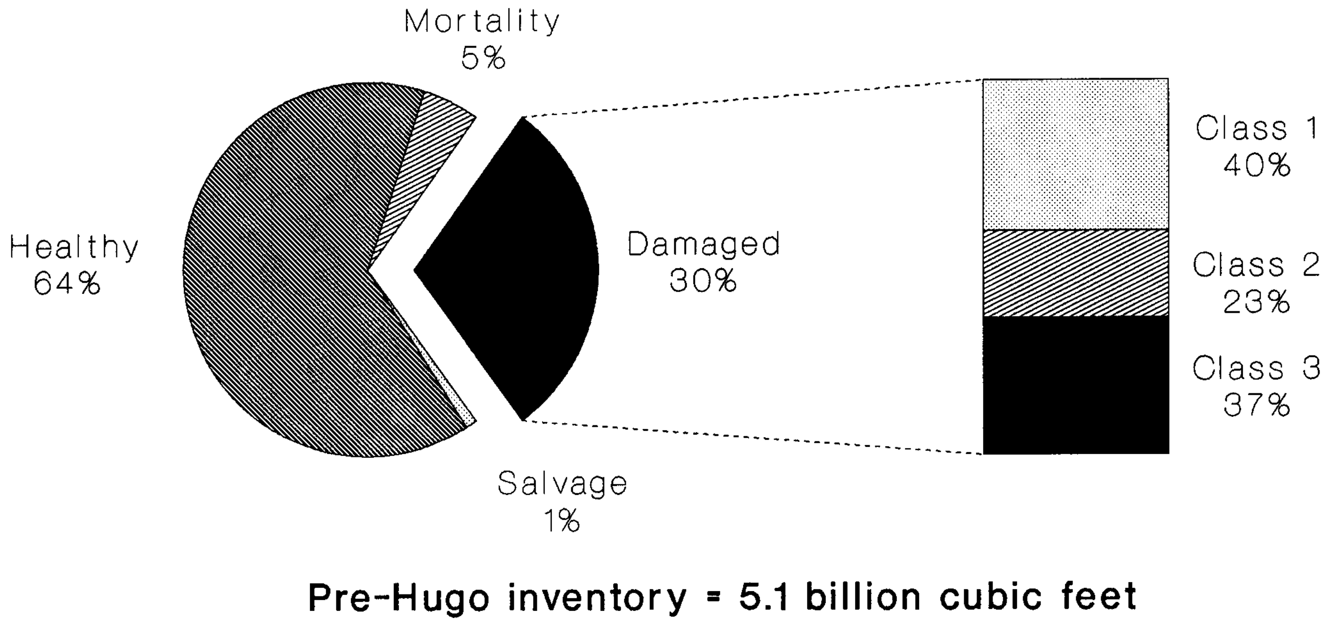

Figure 12—Summary of hurricane losses and damage to the pre-Hugo hardwood inventory.

Hardwood Damage Summary

The fate of the pre-Hugo hardwood inventory is outlined in figure 12. The volume present before the storm was about 5.1 billion cubic feet. Only 5 percent of the pre-Hugo inventory, or 270 million cubic feet, was in trees that were killed outright by the storm. Only 1 percent was removed in salvage operations. Almost 577 million cubic feet, or 11 percent, of the pre-Hugo inventory is now in class 1 trees. Another 385 million cubic feet, or 8 percent, is in class 2 trees and some 577 million cubic feet is in class 3 trees. After subtracting out all Hugo-related damage, salvage, and mortality, about 3.3 billion cubic feet, or 64 percent, of the pre-Hugo hardwood inventory remains in an undamaged state.

Although the immediate loss of hardwoods to Hugo was relatively small (0.3 billion cubic feet of mortality and salvage volume), the potential for additional hardwood mortality and degrade is very high. A reasonable estimate of total hardwood damage is about 20 percent of the pre-Hugo hardwood volume, or 1.0 billion cubic feet. While hardwood mortality will not likely escalate to this level, loss estimates of this magnitude are justified because of the value loss associated with many of the wind-related damages.

Stand Condition Assessment

By any reasonable standard, the timber damage caused by Hurricane Hugo was catastrophic. But people are resilient, and they know that timber is a renewable resource. The people of South Carolina want to know what must be done to get their forests back to normal. And while their forests are recovering, they want to know what the effects on the timber industry will be. Answers to those questions depend on accurate descriptions of stand conditions before and after the storm.

We estimated the stocking of manageable stand (crop) trees just prior to Hurricane Hugo by the method described below. The term "stocking" as used here refers to the degree of occupancy of the land by trees as compared with a minimum standard required to fully utilize the growth potential of the land. Values used are expressed in percentage of full stocking.

(1) Stocking of all tally trees on each plot was summarized to establish the baseline stocking level of each plot at the time of the 1986 inventory. Only trees 3.0 inches d.b.h. and larger in natural stands and 1.0 inch in planted stands were tallied. Furthermore, only trees that were coded as being part of a manageable stand were considered; if a manageable stand did not exist in 1986, stocking of all growing-stock trees was summarized.

(2) Trees that were cut or died after the 1986 inventory but before Hugo were subtracted from the 1986 baseline stocking to establish the pre-Hugo condition or stocking for the stand.

Trees killed by the storm or salvaged soon after are no problem—they must be deducted to estimate current stocking. Assessment of current stocking, however, requires some conjecture about how many of the trees damaged by the storm will make satisfactory crop trees through the end of the timber rotation. Damage to live trees ranges from relatively minor to major and life threatening. Three different assumptions about damaged trees were made:

1. All damaged trees (risk classes 1, 2, and 3) are unsatisfactory for future stocking (maximum stocking reduction).

2. Only class 1 and class 2 trees are unsatisfactory (average reduction).

3. Only class 1 trees are unsatisfactory (minimum reduction).

Trees that were classed as acceptable in 1986 and were not damaged by the storm, plus those trees with light levels of damage, were all considered to be acceptable to retain in the stand until the end of a rotation. Different minimum levels of pre- and post-Hugo manageable stand stocking were used for assessments of regeneration needs and timber supply impacts.

Regeneration Needs Soar

Previous assessments of regeneration treatment opportunity have used 60-percent stocking as a minimum for determining whether a manageable stand exists (Tansey and Hutchins 1988). In 1986, the 23 counties reinventoried contained approximately 1.0 million acres of timberland judged to be in need of regeneration. In this analysis, we have used the same standard for our baseline estimate of added regeneration treatment opportunity. Stands that moved from greater than 60-percent stocking with manageable stand trees to less than 60 percent were included in the summary of additional acres needing regeneration. Pre- and post-Hugo stocking values different from these can also be used to estimate regeneration needs, and an example of this flexibility is demonstrated.

Depending on which live-tree damages were included as stocking reductions, the acreage reduced below minimum-stocking standards ranged from 0.8 to 1.5 million acres (table I). Using the minimum-stocking-reduction scenario discussed above, 0.8 million acres shifted from more than 60 percent stocked with crop trees to less than 60 percent stocked. Under the average discount, 1.2 million acres

Table I--Area of timberland reduced below a manageable stand using different stocking discounts, by broad management class, for 23 counties in South Carolina, 1986-1990

Broad management class	All classes	Damaged area	Stocking reduced below manageable levels using:		
			Minimal discount[a]	Average discount[b]	Maximum discount[c]
			Thousand acres		
Pine plantation	1,208.7	746.7	118.5	220.2	329.7
Natural pine	1,773.8	1,252.9	255.5	332.9	436.1
Oak-pine	832.4	545.4	67.8	105.5	135.1
Upland hardwood	989.2	634.7	102.0	119.0	147.9
Lowland hardwood	1,731.9	1,329.0	267.1	379.5	490.5
All classes	6,536.0	4,508.7	810.9	1,157.1	1,539.3

[a]Stocking reduction consists of Hugo mortality, Hugo salvage, and class 1 live-tree damage.

[b]Stocking reduction consists of Hugo mortality, Hugo salvage, and classes 1 and 2 live-tree damage.

[c]Stocking reduction consists of Hugo mortality, Hugo salvage, and classes 1, 2, and 3 live-tree damage.

were damaged severely enough to place them into a regeneration needs category. If all damaged trees are used as discounts (maximum discount), 1.5 million acres shift into a poorly stocked category. Considering this range, the acreage needing regeneration in these 23 counties has very likely more than doubled because of hurricane-related damages.

The average discount option probably yields the most realistic estimate of regeneration needs. Under the maximum discount, many acres are classed as poorly stocked based on fairly minor damages such as small portions of crown missing or minor degrees of lean and bend. On the other hand, the minimum discount probably understates the area of timberland where the need to start over exists. To a large extent, the decision to regenerate will depend upon the individual landowner's view of what constitutes an acceptable stand.

Under the average discount, stocking was reduced sufficiently on about one-fourth of the 4.5 million affected acres to warrant stand regeneration. Hugo added significant opportunities for regeneration in all types of stands. About 29 percent of damaged pine plantations were determined to be less than adequately stocked with acceptable trees based upon the defined standards. This proportion is as high as that for lowland hardwood and somewhat higher than that for natural pine stands (27 percent). The relatively high proportion of plantations classed as poorly stocked is partially attributable to the more complete evaluation of all potental crop trees in these stands as compared with natural stands. In general, however, the timber expectations of the owners of plantations probably exceed the expectations of the owners of natural stands.

Other minimum levels of stocking for pre-Hugo and post-Hugo conditions could be used to estimate the acreages of regeneration opportunities. Many stands that are moderately stocked with acceptable trees become more fully stocked as the trees grow and as natural regeneration becomes established (Baker 1989). We did not attempt to conduct a more complete evaluation of regeneration needs. Decisions about acceptable stocking are predicated upon many variables, among them site quality, forest type, management objectives, rotation age, and the mix of damages of various degrees and types. However, we do provide a detailed summary of acreage by stand type that displays the pre-Hugo and post-Hugo stocking categories (app. table C.22). Hugo stocking reductions in this table are based upon the average discount option discussed above.

An example of how one might use different combinations of pre- and post-Hugo stocking values to assess damage is presented in table II. Values in boldface type, corresponding to pre-Hugo stocking

Table II--Area of timberland by pre- and post-Hugo stocking percentage for manageable stand trees, for 23 counties in South Carolina, 1986-1990[a]

Pre-Hugo stocking (percent)	All classes	Post-Hugo stocking (percent)								
		0-14	15-29	30-39	40-49	50-59	60-69	70-84	85-99	100+
					Thousand acres					
0-14	1,294.3	1,294.3								
15-29	429.7	84.6	345.1							
30-39	356.1	43.4	62.6	250.1						
40-49	418.1	64.2	57.0	52.7	244.2					
50-59	623.8	89.1	59.5	72.9	86.9	315.4				
60-69	629.5	**56.5**	**63.4**	**53.4**	**72.3**	**95.7**	288.2			
70-84	901.4	**91.1**	**53.6**	**82.9**	**81.8**	65.7	128.9	397.4		
85-99	716.8	**59.8**	**25.5**	**34.7**	**49.2**	24.4	68.2	131.9	323.1	
100+	1,166.3	**89.5**	**45.4**	**41.2**	**26.2**	**44.9**	44.4	104.1	126.7	643.9
All classes	6,536.0	1,872.5	712.1	587.9	560.6	546.1	529.7	633.4	449.8	643.9

[a]Based on trees 3.0 inches d.b.h. and larger in natural stands; all stems, including new planted stems, in plantations.

levels of 60 percent or greater and post-Hugo stocking of less than 60 percent, are those presented in table I under average discount. An alternative assessment of added regeneration opportunity created by Hugo damage is indicated by a summary of acreage below and to the left of the stairstep line through the body of the table. Here, a sliding scale is used to define acceptable. The result depends, to a degree, on pre-Hugo stocking. For instance, stands with a pre-Hugo stocking of 50–59 percent are not included in a regeneration scenario unless stocking has been reduced below 40 percent. Stands 85–99 percent stocked would have to be reduced below 50 percent post-Hugo stocking. This assessment of added regeneration needs yields an estimate of 1.3 million acres, about the same as the estimate using the traditional 60-percent threshold. Appendix table C.22 contains similar data by stand type so readers can conduct their own evaluations.

Regardless of the process and stocking guidelines used to estimate regeneration needs, it is obvious that Hugo added greatly to the already large backlog of acreage that lacked a manageable stand of trees. The additional area easily exceeds 1 million acres. In addition, the estimates presented here are low because small trees in natural stands (< 3.0 inches d.b.h.) were not reinventoried and losses of them were not discounted.

The extent to which natural regeneration will be able to rehabilitate damaged stands cannot be assessed using the Hugo inventory data. Plots were visited too soon after the storm for natural regeneration to have become established. These assessments will be made in a few years during the next full-scale inventory of South Carolina, scheduled for completion by 1993.

Future Timber Supplies Altered

We attempted to roughly assess the effects of the observed damage to stands on the region's future timber supplies. Our analysis did not include a sophisticated projection model. Rather, we assigned each sample stand to a damage class in a process similar to that used for the regeneration analysis. Three damage classes were assigned: no damage, light damage, and moderate/heavy damage. Stands that were harvested since 1986, but before the hurricane struck, were identified and portrayed as a separate category. Magnitude of stocking reduction was the primary consideration in placing each sample plot in one of the hurricane damage categories. The "no damage" category was assigned based upon field crew observation on the ground; this classification was cross-checked against tree tally to verify that no hurricane-damaged trees were present. The remaining stands were assigned to one of two damage groups based upon the severity of the stocking reduction attributed to hurricane damage.

Light damage:

1. Sample plots where pre-Hugo stocking was already below 30 percent of full stocking.

2. Sample plots where post-Hugo stocking remained above 75 percent of full stocking.

3. Sample plot with stocking standards between 1 and 2, where less than one-half of pre-Hugo stocking was lost and stocking reduction as a percentage of full stocking did not exceed 30 percentage points.

Moderate to heavy damage:

All damaged stands not assigned to "light" damage were classified as moderate/heavy damage.

The distribution of damaged acreage is depicted in age profiles (fig. 13). Classifications of stand age and type are based on 1986 conditions in most cases. Changes in these classifications that would be expected with timber cutting, natural disturbances, or stand development were not accounted for. Stands harvested between 1986 and 1990 are identified as a separate category in the profiles so that the timber supply impacts of recently harvested stands can be evaluated concurrently with the impacts of hurricane damage. When planting occurred on a sample plot between 1986 and 1990, the sample was assigned to pine plantation, age class 0. Pine plantations were assigned to a 5-year class, whereas natural stands were assigned to 10-year age classes.

More than 261,000 acres out of 1.2 million acres of pine plantations in the 23 counties were classed as moderately to heavily damaged (fig. 13a). On these areas, Hugo reduced manageable stand stocking by 70 percent based on the average stocking-reduction criteria discussed previously. These stands were left with an average stocking of healthy and class 3 damaged trees of only 28 percent of full stocking. Almost one-third of the nonharvested plantations age 15 and above were classed as moderately to heavily damaged.

Another 475,000 acres (39 percent of all plantations) were classed as lightly damaged. In these stands, Hugo reduced pre-Hugo stocking by an average of 16 percent. However, stocking of healthy and class 3 damaged trees in these stands averaged 81 percent of full stocking—an adequate amount for long-term development of acceptable trees. Pine plantations established since 1986 (age class 0) and those in age classes 5 and 10 account for almost four-fifths of the undamaged pine plantations.

About 400,000 acres of stands classed as natural pine in 1986, and not subsequently harvested, were moderately to heavily damaged (fig. 13b). This acreage represents 25 percent of all nonharvested natural pine stands. The hurricane reduced manageable stand stocking for this group by 77 percent, leaving an average of only one-fifth of full stocking. As with plantations, losses were concentrated in age classes that have the highest volumes. Almost one-third of all unharvested, natural pine stands greater than 20 years old were moderately to heavily damaged. In contrast, only 7 percent of natural pine stands less than 20 years old were so classified.

Light damage was inflicted on 743,000 acres of nonharvested natural pine stands. These stands are found across the range of age classes but make up more than one-half of each of the three youngest age classes for natural pine. Natural pine stands in this category lost 11 percent of their pre-Hugo stocking to the hurricane.

About 17 percent of the stands in oak–pine and hardwood forest types in 1986, and not subsequently harvested, were moderately to heavily damaged (fig. 13c). Altogether, some 582,000 acres of

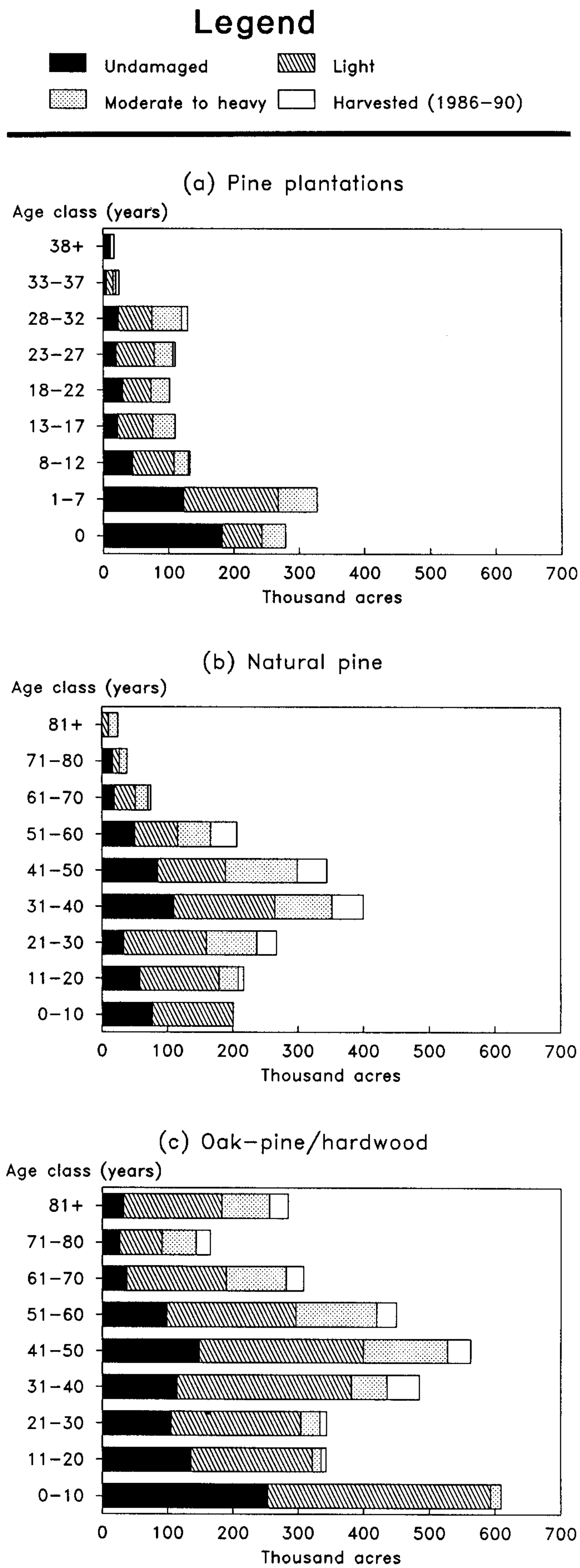

Figure 13—Stand-age profiles for pine plantations, natural pine stands, and oak-pine/hardwood stands, by degree of hurricane damage.

hardwood-dominated timberland were so classified. These severely damaged stands were concentrated in the 41–50 and older age classes. Almost 29 percent of hardwood and oak–pine stands past age 40 were moderately to heavily damaged. Only 7 percent of stands less than 40 years old were placed in that category. In moderately to heavily damaged hardwood and oak–pine stands, Hugo reduced stocking by an average 66 percent. The residual stands (comprised of healthy and class 3 damaged trees) averaged only 26 percent of full stocking.

More than one-half (1.8 million acres) of oak–pine and hardwood stands were lightly damaged. The hurricane reduced manageable stand stocking there by 15 percent. The remaining 1.0 million acres did not sustain any hurricane damage. Oak–pine and hardwood forests that were not damaged or were lightly damaged were distributed across all age classes, but they were more highly concentrated in the younger age classes.

Geographically, forest stands with moderate to heavy damage were distributed in a similar fashion to the volume-loss distributions shown earlier (fig. 14). Moderately to heavily damaged stands are concentrated near the coast and to the northeast side of the hurricane's path.

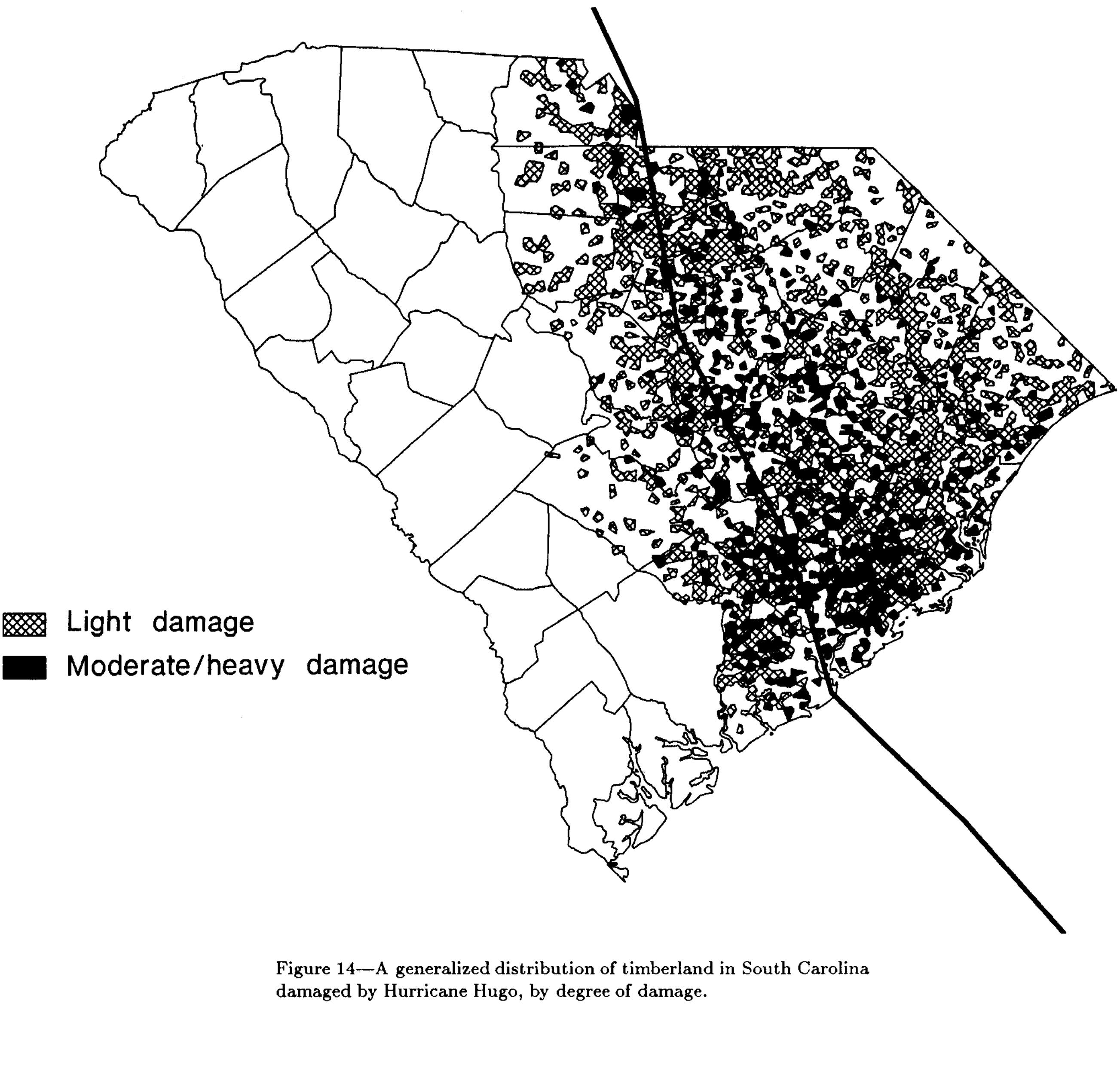

Figure 14—A generalized distribution of timberland in South Carolina damaged by Hurricane Hugo, by degree of damage.

From a timber supply standpoint, Hurricane Hugo had an immediate impact by damaging old, high-volume stands more severely than young, low-volume stands. The age structure of the forests was instantly skewed toward more younger stands. The hurricane also reduced the stocking of residual trees on relatively large areas to a level that requires the establishment of a new, vigorous stand to restore long-term productivity. Regenerating new stands over large areas through planting and natural means will further tilt the age structure toward young stands. Concentrations of very young stands bode well for growth and inventory changes 15 to 20 years in the future. In the interim, however, timber supplies have been severely compromised in the 23 counties. The impact is, and will be, especially severe for both softwood and hardwood solid-wood-product industries. Much depends upon the degree to which (1) trees can respond to the varying degrees of damage without losing substantial value for their best use; and (2) damaged timber can be utilized and make a viable contribution to timber supplies in the short term.

Based on levels of damage depicted in the age profiles, potential timber supplies for the next 10 to 20 years have been reduced by 20–30 percent in the 23 counties. Manufacturers that depend on medium- to large-diameter trees will be impacted for a considerably longer period of time. Supply reductions could easily exceed 30 percent for manufacturers that cannot utilize damaged timber.

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Appendix A: Data-Collection Procedures

In the 23 damaged counties, field crews relocated 2,530 permanent sample plots that were established in timberland in previous inventories. At each sample, crews recorded information about the condition of the stand, noting any treatments or disturbances that had occurred since the previous inventory in 1986. In addition, each stand was visually assessed for evidence of hurricane damage of any severity. Land use changes, windthrow orientation, and a description of the potential for natural pine regeneration were also recorded.

In natural stands, all trees 3.0 inches d.b.h. and larger at the time of the 1986 inventory were relocated. These trees were determined to be either alive, timber removals, or mortality. Live trees were evaluated for several storm-related damages. If a tree had died since the 1986 inventory, its death was attributed to the hurricane or to other natural causes. Likewise, trees removed from timberland by human activity were separated into regular removals and hurricane-related salvage operations.

In planted stands, all trees 1.0 inch d.b.h. and larger in 1986 were accounted for and evaluated in the same manner as above. In addition, pine trees that had grown from less than 1.0 inch d.b.h. to 1.0 inch or larger and all pine seedlings that were considered part of a manageable stand were tallied on 1/300-acre fixed plots at each of the five sample point centers. These "new" pine tally trees were also assessed for hurricane damage.

Stand Condition Variables

The following items were recorded for each sample:

Stand origin. This code identified stands that had evidence of planting or seeding.

Hurricane damage. This code specified whether or not hurricane damage was evident in the sample stand. It did not indicate the severity of the damage.

Past treatment. Up to three past treatments were coded by using standard FIA procedures. Only treatments that occurred between the 1986 survey and the hurricane survey were recorded.

Past disturbance. Any significant natural or human-caused disturbance such as disease, insects, or prescribed fire that occurred after the 1986 survey was identified (not including hurricane damage).

Treatment opportunity. At each sample location, field crews determined what treatments, if any, were needed to improve existing conditions in the stand. Possible recommendations included salvage, harvest, thinning, other stand improvement cuttings, stand conversion, regeneration, and no treatment.

Potential natural pine regeneration. This item was coded to describe the potential of hurricane-damaged stands to regenerate naturally with pine. The coding basically described three situations: stands that had adequate existing regeneration, stands with an adequate seed source (minimum basal area of 10 ft^2/acre), or stands that did not have an adequate seed source.

Nonforest plot (Optional Item 1). This item identified those samples that were cleared to a nonforest land use since 1986.

Throw orientation (Optional Item 2). Field crews, using standard FIA codes for aspect description, coded the predominant orientation of down or leaning trees on the sample acre.

Tree Variables

The following variables were recorded for individual trees on each plot:

Tree history. Each tree tallied was assigned to one of six categories: (1) pine ingrowth, tallied only in plantations; (2) live tree with damage; (3) mortality caused by the hurricane; (4) mortality not caused by the hurricane; (5) tree removed from timberland, not associated with a salvage cutting operation; and (6) tree removed as a result of a salvage cutting or cleanup operation. Live trees without damage were not entered on the field forms; information for these trees was extracted from computer files for the 1986 inventory.

Species. A three-digit standard FIA species code was assigned to each tree tallied.

Old d.b.h. The d.b.h. assigned in the 1986 survey was transferred to the tally sheet used in the Hugo inventory.

Tree class. A tree class code was assigned to each live tree tallied using FIA merchantability standards. Tree class was not changed from that coded in the 1986 survey unless it changed as a result of hurricane-inflicted damage.

Cubic-volume loss. An estimate of the percentage of the tree's merchantable volume missing because of hurricane damage.

Percentage of crown missing. An estimate of the percentage of live-tree crown lost because of hurricane-related damage. The crown ratio code noted in the 1986 survey was used as a base for making this determination.

Terminal leader missing. The absence of the tree's terminal leader was recorded if the breakage was caused by the storm.

Bole condition. Any damage to the bole of the tree was coded if the damage was caused by the hurricane. On a priority basis, injuries were coded as: (0) no damage, (1) split or twisted bole, (2) debris driven into tree, and (3) tree bole skinned through cambium.

Tree lean. The angle of lean was recorded for each live tree. Lean was defined as the degree from which the first 12-foot section of the tree varied from the vertical axis. A code of "00" was recorded for a tree with no deviation from vertical axis associated with hurricane winds. A code of "90" was used to describe a live tree lying on the ground.

Tree bend. Tree bend was coded in the same manner as tree lean except it was measured from the ground to the tip of the tree.

Distance to breakage. If the bole of a tree was broken due to wind damage, the distance in feet from the 1-foot stump to the point of breakage was recorded.

Root damage. The field crews looked for any evidence that the tree's root system had been damaged by the storm. Root injuries were recorded as: (1) no root damage, (2) roots exposed (root sprung), and (3) root damage below ground.

Cut-mortality period. For each tree tallied that had either died or was cut before the hurricane (tree history 6 or 8), a code was assigned to describe when the mortality or removal occurred. If the mortality or removal occurred within the past year, a 1 was recorded; 2 years ago, a 2 was recorded.

Salt burn. Field crews assigned a code to indicate the presence of crown damage from airborne saltwater spray. The brown or red foliage associated with this damage was treated as missing crown.

HUGO DAMAGE ASSESSMENT SURVEY — December 1989

State	Unit	County	Location	Stand Origin	Hurricane Damage	Past Treat. 1	Past Treat. 2	Past Treat. 3	Past Dist.	Treat. Opp.	Poten. Nat. Pine Regen.	Optional	Optional
XX	X	XX	XXX	X	X	X	X	X	X	X	X	X	X

Tallyperson ________ Date ________

Cruiser ____________

Field Notes ____________

Point Number	Tree Number	Tree History	Species	Old DBH	Tree Class	Cu. Vol Loss (By Hugo)	Percent of Crown Missing	Term.Missing	BoleCondition	Tree Lean	Tree Bend	Distance to Breakage	Root Damage	Cut/Mort Per.	Optional
X	XX	X	XXX	XXX	X	XX	XX	X	X	XX	XX	XX	X	X	X

Code

HURRICANE DAMAGE

0 - No damage
1 - Hurricane effects evident on sample acre

POTENTIAL NATURAL PINE REGENERATION

1 - Adequate existing
2 - Pine seed source exists (favorable)
3 - Pine seed source exists (site prep)
4 - Pine seed source does not exist

TREE HISTORY

2 - Pine ingrowth (plantation only)
3 - Live tree damaged
4 - Hurricane mortality
6 - Mortality before hurricane
8 - Cut not associated with salvage
0 - Tree removed as result of storm

TERM. LDR. MISSING

0 - No
1 - Yes

BOLE CONDITION

0 - No damage
1 - Splits and/or twist
2 - Debris driven into tree
3 - Tree skinned thru cambium

ROOT DAMAGE

0 - No root damage
1 - Roots exposed
2 - Damage below ground

CUT/MORT. PERIOD

1 - 1 year
2 - 2 years
(etc.)

Appendix B: Procedures and Criteria for Assigning Trees With Hurricane Damage into Damage Risk Categories

The 1990 inventory includes all trees that were alive at the time field crews visited each sample location. Several kinds of damage were tallied during the Hugo inventory, and they can occur singly or in multiples in any combination. This appendix documents the procedures and criteria used to assign trees to categories of damage that reflect the tree's risk of dying or its present or potential value loss.

Damage/Risk Class Definition

The damage/risk classes utilized are defined below. The terms "class 1," "class 2," and "class 3" are used instead of descriptive adjectives such as "severe," "moderate," or "light" so that users will review the definitions and criteria and attach descriptions that fit each person's assessment and use of the data.

Class	Description
1	High-risk trees with a high probability of mortality in the near future. Damage is so severe that retention in the stand until the end of a rotation is not feasible.
2	Moderate-risk trees with an elevated risk of dying soon. Death is not as "imminent" as in class 1. Damage significantly degrades present or potential value, especially for high-value uses such as saw logs and veneer logs. Tree growth is likely to be reduced for a number of years due to damages such as loss of crown or root damage. Retention in the stand is questionable and depends on tree and stand age, product objectives, etc.
3	Low-risk trees with a high probability of survival. Damage elevates the risk of mortality, but reduced growth and value degrade will probably be minimal.
4	Trees without obvious hurricane damage.

Criteria and Evaluation Procedure

Criteria for assigning trees to damage/risk classes are provided for the following combinations of species, stand type, and tree size or age class:

Softwood species in planted stands–
- Less than 5 years old
- 5–20 years old
- 21 years and older

Softwood species in natural stands–
- Saplings (1.0–4.9 inches)
- Poletimber (5.0–8.9 inches)
- Sawtimber (9.0 inches & larger)

Hardwood species in all stands–
- Saplings (1.0–4.9 inches)
- Poletimber (5.0–10.9 inches)
- Sawtimber (11.0 inches & larger)

The following procedure was used to make the damage/risk class assignment for each tree.

- Class 4 (healthy) was assigned if no obvious hurricane damage was present.
- Class 1 was assigned if one (or more) qualifying damage was present. When listed, associated damages were treated as a required combination with the primary condition.
- If the criteria for assignment to class 1 were not met, then criteria for class 2 were evaluated in the same manner as described above.
- If no damages listed for class 2 were present, then damage assignment defaulted to class 3.

The damage variables coded for each tree and used in the damage/risk classification process are described in appendix A.

Table B.1--Damage/risk class criteria for softwood species in pine plantations less than 5 years old

Damage/risk class	Primary condition	Associated condition
4 (healthy)	No obvious damage	
1	Crown loss ≥ 75%	
	Root sprung	
	Split/twisted bole	
	Lean/bend ≥ 60 degrees	
	Salt burn present	Crown loss ≥ 30%
	Volume loss (residual trees) ≥ 30%	
2	Crown loss 40-74%	
	Lean/bend 15-59 degrees	
	Salt burn present	Crown loss < 30%
	Volume loss (residual trees) 10-29%	
	Terminal leader broken out	
3	Crown loss 1-39%	
	Root damage below ground	
	Skinned bole/other bole damage	
	Lean/bend 1-14 degrees	
	Volume loss (residual trees) 1-9%	

Table B.2--Damage/risk class criteria for softwood species in pine plantations 5-20 years old

Damage/risk class	Primary condition	Associated condition
4 (healthy)	No obvious damage	
1	Crown loss ≥ 75%	
	Root sprung	
	Split/twisted bole	Crown loss ≥ 50%
	Lean/bend ≥ 45 degrees	
	Salt burn present	Crown loss ≥ 30%
	Volume loss ≥ 30%	
2	Crown loss 40-74%	
	Lean/bend 15-44 degrees	
	Split/twisted bole	Crown loss < 50%
	Skinned bole/other bole damage	Crown loss ≥ 25%
	Salt burn present	Crown loss < 30%
	Terminal leader broken out	
	Volume loss 5-29%	
3	Crown loss 1-39%	
	Root damage below ground	
	Skinned bole/other bole damage	Crown loss < 25%
	Lean/bend 1-14 degrees	
	Volume loss 1-4%	

Table B.3--Damage/risk class criteria for softwood species in pine plantations greater than 20 years old

Damage/risk class	Primary condition	Associated condition
4 (healthy)	No obvious damage	
1	Crown loss ≥ 75%	
	Root sprung	
	Split/twisted bole	Crown loss ≥ 50%
	Lean/bend ≥ 35 degrees	
	Salt burn present	Crown loss ≥ 30%
	Volume loss ≥ 30%	
2	Crown loss 40-74%	
	Lean/bend 15-34 degrees	
	Split/twisted bole	Crown loss < 50%
	Skinned bole/other bole damage	Crown loss ≥ 25%
	Salt burn present	Crown loss < 30%
	Volume loss 5-29%	
3	Crown loss 1-39%	
	Root damage below ground	
	Skinned bole/other bole damage	Crown loss < 25%
	Lean/bend 1-14 degrees	
	Terminal leader broken out	
	Volume loss 1-4%	

Table B.4--Damage/risk class criteria for softwood saplings (1.0-4.9 inches d.b.h.) in natural stands

Damage/risk class	Primary condition	Associated condition
4 (healthy)	No obvious damage	
1	Crown loss ≥ 75%	Dominant/codominant trees
	Crown loss ≥ 50 %	Intermediate/suppressed trees
	Root sprung	
	Split/twisted bole	Crown loss ≥ 50%
	Salt burn present	Crown loss ≥ 30%
	Lean/bend ≥ 45 degrees	
2	Crown loss 40-74%	Dominant/codominant trees
	Crown loss 25-49%	Intermediate/suppressed trees
	Split/twisted bole	Crown loss < 50%
	Skinned bole/other bole damage	Crown loss ≥ 25%
	Lean/bend 15-44 degrees	
	Salt burn present	Crown loss < 30%
	Terminal leader broken out	
3	Crown loss 1-39%	Dominant/codominant trees
	Crown loss 1-25%	Intermediate/suppressed trees
	Root damage below ground	
	Skinned bole/other bole damage	Crown loss < 25%
	Lean/bend 1-14 degrees	

Table B.5--Damage/risk class criteria for softwood poletimber (5.0-8.9 inches d.b.h.) in natural stands

Damage/risk class	Primary condition	Associated condition
4 (healthy)	No obvious damage	
1	Crown loss ≥ 75%	Dominant/codominant trees
	Crown loss ≥ 50%	Intermediate/suppressed trees
	Root sprung	
	Split/twisted bole	Crown loss ≥ 50%
	Lean/bend ≥ 45 degrees	
	Salt burn present	Crown loss ≥ 30%
	Volume loss ≥ 30%	
2	Crown loss 40-74%	Dominant/codominant trees
	Crown loss 25-49%	Intermediate/suppressed trees
	Split/twisted bole	Crown loss < 50%
	Skinned bole/other bole damage	Crown loss ≥ 25%
	Lean/bend 15-44 degrees	
	Salt burn present	Crown loss < 30%
	Volume loss 5-29%	
	Terminal leader broken out	
3	Crown loss 1-39%	Dominant/codominant trees
	Crown loss 1-25%	Intermediate/suppressed trees
	Root damage below ground	
	Skinned bole/other bole damage	Crown loss < 25%
	Lean/bend 1-14 degrees	
	Volume loss 1-4%	

Table B.6--Damage/risk class criteria for softwood sawtimber (9.0 inches d.b.h. and larger) in natural stands

Damage/risk class	Primary condition	Associated condition
4 (healthy)	No obvious damage	
1	Crown loss ≥ 75%	Dominant/codominant trees
	Crown loss ≥ 50 %	Intermediate/suppressed trees
	Root sprung	
	Split/twisted bole	Crown loss ≥ 50%
	Lean/bend ≥ 35 degrees	
	Salt burn present	Crown loss ≥ 30%
	Volume loss ≥ 30%	
2	Crown loss 40-74%	Dominant/codominant trees
	Crown loss 25-49%	Intermediate/suppressed trees
	Split/twisted bole	Crown loss < 50%
	Skinned bole/other bole damage	Crown loss ≥ 25%
	Lean/bend 15-34 degrees	
	Salt burn present	Crown loss < 30%
	Volume loss 5-29%	
3	Crown loss 1-39%	Dominant/codominant trees
	Crown loss 1-25%	Intermediate/suppressed trees
	Root damage below ground	
	Skinned bole/other bole damage	Crown loss < 25%
	Lean/bend 1-14 degrees	
	Terminal leader broken out	
	Volume loss 1-4%	

Table B.7--Damage/risk class criteria for hardwood saplings (1.0-4.9 inches d.b.h.)

Damage/risk class	Primary condition	Associated condition
4 (healthy)	No obvious damage	
1	Crown loss ≥ 90%	
	Root sprung	Lean/bend ≥ 45 degrees
	Split/twisted bole	Crown loss ≥ 75%
	Lean/bend ≥ 75 degrees	
2	Crown loss 45-89%	
	Split/twisted bole	Crown loss < 75%
	Skinned bole/other bole damage	
	Lean/bend 15-74 degrees	
3	Crown loss 1-44%	
	Root damage below ground	
	Lean/bend 1-14 degrees	
	Terminal leader broken out	

Table B.8--Damage/risk class criteria for hardwood poletimber (5.0-10.9 inches d.b.h.)

Damage/risk class	Primary condition	Associated condition
4 (healthy)	No obvious damage	
1	Crown loss $\geq$ 90%	
	Root sprung	Lean/bend $\geq$ 35 degrees
	Split/twisted bole	Crown loss $\geq$ 75%, or
		Bole breakage in lower 20 ft
	Lean/bend $\geq$ 60 degrees	
	Volume loss $\geq$ 30%	
2	Crown loss 45-89%	
	Root sprung	Lean/bend < 35 degrees
	Split/twisted bole	Crown loss < 75%, or
		Bole breakage above lower 20 ft
	Skinned bole/other bole damage	
	Lean/bend 15-59 degrees	
	Volume loss 5-29%	
3	Crown loss 1-44%	
	Root damage below ground	
	Lean/bend 1-14 degrees	
	Terminal leader broken out	
	Volume loss 1-4%	

Table B.9--Damage/risk class criteria for hardwood sawtimber (11.0 inches d.b.h. and larger)

Damage/risk class	Primary condition	Associated condition
4 (healthy)	No obvious damage	
1	Crown loss ≥ 90%	
	Root sprung	Lean/bend ≥ 25 degrees
	Split/twisted bole	Crown loss ≥ 75%, or
		Bole breakage in lower 20 ft
	Lean/bend ≥ 45 degrees	
	Volume loss ≥ 30%	
2	Crown loss 45-89%	
	Root sprung	Lean/bend < 25 degrees
	Split/twisted bole	Crown loss < 75%, or
		Bole breakage above lower 20 ft
	Skinned bole/other bole damage	
	Lean/bend 15-44 degrees	
	Volume loss 5-29%	
3	Crown loss 1-44%	
	Root damage below ground	
	Lean/bend 1-14 degrees	
	Terminal leader broken out	
	Volume loss 1-4%	

Appendix C: Detailed Tables

Table C.1--Period change in volume of softwood growing stock on timberland, by county and component of change, for 23 counties in South Carolina, 1986-1990

County	1986 inventory (I_{86})	Gross growth (GG)	Regular mortality (M_r)	Hugo mortality (M_h)	Net growth (NG)	Regular removals (TR_r)	Hugo removals (TR_h)	Net change (NC)	1990 inventory (I_{90})
					Thousand cubic feet				
Berkeley	542,202	109,040	6,850	212,364	-110,174	49,770	79,184	-239,128	303,074
Calhoun	119,407	22,235	--	17,782	4,453	23,709	8,767	-28,023	91,384
Charleston	305,111	43,414	4,106	112,201	-72,893	34,329	34,258	-141,480	163,631
Chester	223,223	58,451	5,967	15,992	36,492	27,939	11,219	-2,666	220,557
Chesterfield	206,712	50,990	4,621	13,737	32,632	21,357	10,815	460	207,172
Clarendon	138,435	20,492	995	35,522	-16,025	17,752	27,956	-61,733	76,702
Darlington	102,759	15,903	388	6,563	8,952	11,404	15,607	-18,059	84,700
Dillon	96,508	19,530	2,781	2,051	14,698	11,044	5,505	-1,851	94,657
Dorchester	226,376	31,316	4,585	20,689	6,042	53,544	13,325	-60,827	165,549
Fairfield	286,611	90,995	11,613	867	78,515	68,972	--	9,543	296,154
Florence	242,192	42,479	5,208	18,659	18,612	78,253	6,884	-66,525	175,667
Georgetown	285,312	54,223	5,694	29,100	19,429	69,430	9,960	-59,961	225,351
Horry	388,917	67,958	5,349	4,883	57,726	71,594	3,672	-17,540	371,377
Kershaw	185,948	42,864	2,840	13,941	26,083	65,993	13,961	-53,871	132,077
Lancaster	158,758	46,947	4,785	19,332	22,830	46,096	35,403	-58,669	100,089
Lee	85,669	16,707	4,064	15,963	-3,320	14,788	12,603	-30,711	54,958
Marion	158,473	27,006	3,519	4,930	18,557	35,361	4,858	-21,662	136,811
Marlboro	92,880	24,812	5,308	2,845	16,659	9,648	--	7,011	99,891
Orangeburg	211,080	38,538	7,302	14,837	16,399	68,385	838	-52,824	158,256
Richland	161,380	35,327	3,239	4,288	27,800	38,963	1,340	-12,503	148,877
Sumter	146,349	26,157	632	31,405	-5,880	18,278	36,545	-60,703	85,646
Williamsburg	271,340	49,581	3,262	28,513	17,806	40,336	41,344	-63,874	207,466
York	179,464	46,536	3,894	5,625	37,017	37,760	1,669	-2,412	177,052
Total	4,815,106	981,501	97,002	632,089	252,410	914,705	375,713	-1,038,008	3,777,098

$NG = GG - M_r - M_h$

$NC = NG - TR_r - TR_h$

$I_{90} = I_{86} + NC$

Pre-Hugo inventory = $I_{86} + GG - M_r - TR_r$

Table C.2--Period change in volume of hardwood growing stock on timberland, by county and component of change, for 23 counties in South Carolina, 1986-1990

County	1986 inventory (I_{86})	Gross growth (GG)	Regular mortality (M_r)	Hugo mortality (M_h)	Net growth (NG)	Regular removals (TR_r)	Hugo removals (TR_h)	Net change (NC)	1990 inventory (I_{90})
					Thousand cubic feet				
Berkeley	327,876	40,760	2,154	43,800	-5,194	17,432	4,507	-27,133	300,743
Calhoun	92,800	12,516	2,762	1,352	8,402	7,478	--	924	93,724
Charleston	200,928	28,375	2,579	33,279	-7,483	3,996	1,848	-13,327	187,601
Chester	137,300	27,138	6,119	--	21,019	24,025	789	-3,795	133,505
Chesterfield	185,278	30,261	4,818	6,457	18,986	23,973	2,532	-7,519	177,759
Clarendon	230,430	28,114	3,141	23,217	1,756	36,608	6,304	-41,156	189,274
Darlington	109,084	20,115	5,578	5,223	9,314	11,560	1,107	-3,353	105,731
Dillon	154,598	25,581	5,186	829	19,566	14,038	--	5,528	160,126
Dorchester	279,752	39,117	2,121	26,983	10,013	49,858	3,168	-43,013	236,739
Fairfield	156,521	29,059	3,553	1,562	23,944	18,955	--	4,989	161,510
Florence	243,874	38,520	5,243	3,576	29,701	28,427	2,468	-1,194	242,680
Georgetown	241,573	33,970	2,575	15,794	15,601	16,146	--	-545	241,028
Horry	438,325	62,908	10,945	5,576	46,387	29,432	544	16,411	454,736
Kershaw	139,303	23,356	1,821	4,810	16,725	6,821	5,097	4,807	144,110
Lancaster	145,246	27,424	1,491	7,065	18,868	20,109	1,782	-3,023	142,223
Lee	93,000	14,129	2,172	24,936	-12,979	906	10,144	-24,029	68,971
Marion	278,067	41,113	8,349	3,585	29,179	35,278	--	-6,099	271,968
Marlboro	185,825	31,881	7,076	1,255	23,550	7,396	--	16,154	201,979
Orangeburg	399,404	60,739	7,684	25,613	27,442	67,927	--	-40,485	358,919
Richland	208,577	33,048	976	--	32,072	31,807	--	265	208,842
Sumter	240,320	25,611	3,660	18,536	3,415	32,794	1,108	-30,487	209,833
Williamsburg	341,219	44,945	6,473	11,165	27,307	32,323	7,604	-12,620	328,599
York	172,963	37,539	3,475	5,752	28,312	14,848	--	13,464	186,427
Total	5,002,263	756,219	99,951	270,365	385,903	532,137	49,002	-195,236	4,807,027

$NG = GG - M_r - M_h$

$NC = NG - TR_r - TR_h$

$I_{90} = I_{86} + NC$

Pre-Hugo inventory = $I_{86} + GG - M_r - TR_r$

Table C.3--Period change in volume of softwood sawtimber on timberland, by county and component of change, for 23 counties in South Carolina, 1986-1990

County	1986 inventory (I_{86})	Gross growth (GG)	Regular mortality (M_r)	Hugo mortality (M_h)	Net growth (NG)	Regular removals (TR_r)	Hugo removals (TR_h)	Net change (NC)	1990 inventory (I_{90})
					Thousand board feet				
Berkeley	2,187,329	457,920	24,755	1,056,557	-623,392	206,824	401,878	-1,232,094	955,235
Calhoun	467,356	103,953	--	91,698	12,255	117,130	30,941	-135,816	331,540
Charleston	1,441,830	240,403	23,332	618,091	-401,020	171,591	147,708	-720,319	721,511
Chester	732,457	238,739	10,087	64,428	164,224	97,552	48,082	18,590	751,047
Chesterfield	737,529	175,947	10,869	65,188	99,890	68,510	64,203	-32,823	704,706
Clarendon	645,232	106,844	5,225	189,637	-88,018	84,499	156,309	-328,826	316,406
Darlington	503,643	84,725	--	35,691	49,034	42,818	92,544	-86,328	417,315
Dillon	434,423	97,447	12,038	9,036	76,373	46,500	12,441	17,432	451,855
Dorchester	981,052	171,850	12,736	88,252	70,862	251,452	60,504	-241,094	739,958
Fairfield	944,591	333,560	38,302	5,796	289,462	257,110	--	32,352	976,943
Florence	1,081,686	219,601	12,189	83,966	123,446	406,868	41,575	-324,997	756,689
Georgetown	1,101,589	243,088	17,887	120,519	104,682	282,164	52,598	-230,080	871,509
Horry	1,684,945	357,104	19,691	21,580	315,833	313,535	22,726	-20,428	1,664,517
Kershaw	599,675	159,297	4,763	47,804	106,730	281,483	42,781	-217,534	382,141
Lancaster	460,865	163,457	15,177	78,051	70,229	179,249	114,594	-223,614	237,251
Lee	329,786	79,405	17,347	76,085	-14,027	39,728	58,605	-112,360	217,426
Marion	738,661	132,876	8,467	25,471	98,938	165,405	31,247	-97,714	640,947
Marlboro	284,079	109,509	14,701	12,024	82,784	13,459	--	69,325	353,404
Orangeburg	821,700	173,864	16,598	73,963	83,303	298,618	5,243	-220,558	601,142
Richland	614,031	138,011	11,046	13,919	113,046	169,727	5,610	-62,291	551,740
Sumter	589,302	114,150	4,499	161,826	-52,175	70,214	166,000	-288,389	300,913
Williamsburg	1,150,983	239,312	17,293	125,738	96,281	186,757	210,728	-301,204	849,779
York	476,528	185,890	10,200	15,646	160,044	144,672	7,419	7,953	484,481
Total	19,009,272	4,326,952	307,202	3,080,966	938,784	3,895,865	1,773,736	-4,730,817	14,278,455

$NG = GG - M_r - M_h$

$NC = NG - TR_r - TR_h$

$I_{90} = I_{86} + NC$

Pre-Hugo inventory = $I_{86} + GG - M_r - TR_r$

Table C.4--Period change in volume of hardwood sawtimber on timberland, by county and component of change, for 23 counties in South Carolina, 1986-1990

County	1986 inventory (I_{86})	Gross growth (GG)	Regular mortality (M_r)	Hugo mortality (M_h)	Net growth (NG)	Regular removals (TR_r)	Hugo removals (TR_h)	Net change (NC)	1990 inventory (I_{90})
					Thousand board feet				
Berkeley	1,018,776	136,093	1,778	148,919	-14,604	62,807	17,616	-95,027	923,749
Calhoun	272,262	47,983	8,944	6,717	32,322	10,276	--	22,046	294,308
Charleston	580,532	98,285	8,504	135,829	-46,048	6,563	2,359	-54,970	525,562
Chester	347,994	74,016	22,747	--	51,269	87,830	--	-36,561	311,433
Chesterfield	563,124	102,595	8,995	20,747	72,853	104,544	6,581	-38,272	524,852
Clarendon	731,638	111,183	5,805	80,820	24,558	124,594	24,318	-124,354	607,284
Darlington	330,963	45,281	20,080	24,282	919	34,284	4,398	-37,763	293,200
Dillon	452,454	87,923	10,011	4,606	73,306	25,212	--	48,094	500,548
Dorchester	856,940	120,240	5,823	102,641	11,776	171,302	17,054	-176,580	680,360
Fairfield	396,366	97,931	11,014	7,508	79,409	67,804	--	11,605	407,971
Florence	833,389	144,036	16,968	18,621	108,447	101,370	11,406	-4,329	829,060
Georgetown	766,458	122,049	3,606	52,253	66,190	41,442	--	24,748	791,206
Horry	1,388,656	230,958	37,015	17,706	176,237	105,446	2,234	68,557	1,457,213
Kershaw	386,776	74,687	1,845	9,650	63,192	15,353	10,288	37,551	424,327
Lancaster	316,751	60,101	2,613	11,512	45,976	59,701	5,808	-19,533	297,218
Lee	287,548	40,512	11,089	97,252	-67,829	2,305	35,931	-106,065	181,483
Marion	910,854	148,097	28,013	16,062	104,022	133,392	--	-29,370	881,484
Marlboro	520,285	108,559	26,789	4,693	77,077	35,886	--	41,191	561,476
Orangeburg	1,054,692	192,056	17,905	76,142	98,009	205,605	--	-107,596	947,096
Richland	667,731	121,999	3,913	--	118,086	120,226	--	-2,140	665,591
Sumter	832,963	106,070	6,869	73,646	25,555	129,359	1,275	-105,079	727,884
Williamsburg	1,064,967	156,556	20,462	44,165	91,929	96,356	24,755	-29,182	1,035,785
York	362,376	106,140	10,970	21,248	73,922	53,044	--	20,878	383,254
Total	14,944,495	2,533,350	291,758	975,019	1,266,573	1,794,701	164,023	-692,151	14,252,344

$NG = GG - M_r - M_h$

$NC = NG - TR_r - TR_h$

$I_{90} = I_{86} + NC$

Pre-Hugo inventory = $I_{86} + GG - M_r - TR_r$

Table C.5--Distribution of 1990 inventory of growing stock, by county, species group, and damage class, for 23 counties in South Carolina

County	Softwoods					Hardwoods				
	1990 Inventory	Percentage of inventory in--				1990 Inventory	Percentage of inventory in--			
		Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees		Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand cubic feet	Percent				Thousand cubic feet	Percent			
Berkeley	303,074	30	28	24	18	300,743	33	18	21	28
Calhoun	91,384	97	1	--	2	93,724	96	--	1	3
Charleston	163,631	64	9	13	14	187,601	53	17	17	13
Chester	220,557	98	--	--	2	133,505	98	1	1	--
Chesterfield	207,172	69	28	2	1	177,759	43	39	7	11
Clarendon	76,702	40	24	15	21	189,274	38	9	9	44
Darlington	84,700	97	--	2	1	105,731	76	1	10	13
Dillon	94,657	100	--	--	--	160,126	92	--	1	7
Dorchester	165,549	69	10	11	10	236,739	69	8	12	11
Fairfield	296,154	99	--	1	--	161,510	100	--	--	--
Florence	175,667	54	30	9	7	242,680	51	24	6	19
Georgetown	225,351	61	10	20	9	241,028	61	15	11	13
Horry	371,377	60	23	16	1	454,736	68	21	6	5
Kershaw	132,077	73	12	11	4	144,110	64	12	6	18
Lancaster	100,089	81	5	2	12	142,223	79	2	5	14
Lee	54,958	72	7	16	5	68,971	54	10	17	19
Marion	136,811	92	3	3	2	271,968	87	3	4	6
Marlboro	99,891	95	2	3	--	201,979	95	2	1	2
Orangeburg	158,256	85	7	6	2	358,919	91	3	4	2
Richland	148,877	93	5	1	1	208,842	85	10	1	4
Sumter	85,646	43	21	16	20	209,833	51	8	15	26
Williamsburg	207,466	38	41	11	10	328,599	38	27	14	21
York	177,052	87	7	3	3	186,427	90	1	2	7
Total	3,777,098	71	14	9	6	4,807,027	68	12	8	12

Table C.6--Distribution of 1990 inventory of sawtimber, by county, species group, and damage class, for 23 counties in South Carolina

County	Softwoods					Hardwoods				
	1990 Inventory	Percentage of inventory in--				1990 Inventory	Percentage of inventory in--			
		Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees		Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand board feet	Percent				Thousand board feet	Percent			
Berkeley	955,235	32	29	20	19	923,749	31	16	22	31
Calhoun	331,540	98	1	--	1	294,308	94	--	1	5
Charleston	721,511	63	9	12	16	525,562	46	21	18	15
Chester	751,047	98	--	--	2	311,433	97	2	1	--
Chesterfield	704,706	69	27	2	2	524,852	43	39	4	14
Clarendon	316,406	35	25	14	26	607,284	25	8	11	56
Darlington	417,315	97	--	2	1	293,200	72	2	12	14
Dillon	451,855	100	--	--	--	500,548	90	--	1	9
Dorchester	739,958	72	9	11	8	680,360	58	10	15	17
Fairfield	976,943	100	--	--	--	407,971	100	--	--	--
Florence	756,689	53	30	9	8	829,060	43	29	5	23
Georgetown	871,509	60	9	21	10	791,206	59	14	10	17
Horry	1,664,517	60	25	14	1	1,457,213	64	23	7	6
Kershaw	382,141	79	11	5	5	424,327	51	13	6	30
Lancaster	237,251	78	1	1	20	297,218	76	1	5	18
Lee	217,426	77	6	10	7	181,483	54	11	15	20
Marion	640,947	94	2	2	2	881,484	87	2	3	8
Marlboro	353,404	94	3	2	1	561,476	94	4	--	2
Orangeburg	601,142	88	9	2	1	947,096	91	3	4	2
Richland	551,740	90	8	1	1	665,591	80	14	1	5
Sumter	300,913	47	19	15	19	727,884	49	8	15	28
Williamsburg	849,779	39	42	9	10	1,035,785	34	27	12	27
York	484,481	86	10	1	3	383,254	88	--	4	8
Total	14,278,455	72	14	8	6	14,252,344	63	13	8	16

Table C.7--Period change in volume of softwood growing stock on timberland, by component of change and ownership class, for 23 counties in South Carolina, 1986-1990

Inventory item	All ownerships	National forest	Other public	Forest industry	Farmer	Miscellaneous private
			Thousand cubic feet			
1986 Inventory (I_{86})	4,815,106	354,368	281,936	1,080,693	1,220,060	1,878,049
Gross growth (GG)	981,501	57,922	59,914	265,970	226,911	370,784
Regular mortality (M_r)	97,002	6,509	6,118	19,662	28,590	36,123
Hugo mortality (M_h)	632,089	167,707	36,395	87,696	131,121	209,170
Net growth (NG)	252,410	-116,294	17,401	158,612	67,200	125,491
Regular removals (TR_r)	914,705	30,360	28,844	291,625	222,433	341,443
Hugo removals (TR_h)	375,713	11,107	15,881	40,317	107,038	201,370
Net change (NC)	-1,038,008	-157,761	-27,324	-173,330	-262,271	-417,322
1990 Inventory (I_{90})	3,777,098	196,607	254,612	907,363	957,789	1,460,727

$NG = GG - M_r - M_h$
$NC = NG - TR_r - TR_h$
$I_{90} = I_{86} + NC$
Pre-Hugo inventory = $I_{86} + GG - M_r - TR_r$

Table C.8--Period change in volume of hardwood growing stock on timberland, by component of change and ownership class, for 23 counties in South Carolina, 1986-1990

Inventory item	All ownerships	National forest	Other public	Forest industry	Farmer	Miscellaneous private
			Thousand cubic feet			
1986 Inventory (I_{86})	5,002,263	184,892	86,205	1,090,291	1,514,479	2,126,396
Gross growth (GG)	756,219	24,689	15,901	151,846	238,050	325,733
Regular mortality (M_r)	99,951	2,988	1,718	21,171	38,820	35,254
Hugo mortality (M_h)	270,365	37,249	6,313	47,490	75,647	103,666
Net growth (NG)	385,903	-15,548	7,870	83,185	123,583	186,813
Regular removals (TR_r)	532,137	19,925	6,598	158,503	135,597	211,514
Hugo removals (TR_h)	49,002	207	--	4,953	23,623	20,219
Net change (NC)	-195,236	-35,680	1,272	-80,271	-35,637	-44,920
1990 Inventory (I_{90})	4,807,027	149,212	87,477	1,010,020	1,478,842	2,081,476

$NG = GG - M_r - M_h$
$NC = NG - TR_r - TR_h$
$I_{90} = I_{86} + NC$
Pre-Hugo inventory = $I_{86} + GG - M_r - TR_r$

Table C.9--Period change in volume of softwood sawtimber on timberland, by component of change and ownership class, for 23 counties in South Carolina, 1986-1990

Inventory item	All ownerships	National forest	Other public	Forest industry	Farmer	Miscellaneous private
				Thousand board feet		
1986 Inventory (I_{86})	19,009,272	1,623,832	1,069,257	3,492,092	5,185,255	7,638,836
Gross growth (GG)	4,326,952	266,259	226,353	1,013,555	1,106,316	1,714,469
Regular mortality (M_r)	307,202	23,437	15,112	44,469	96,839	127,345
Hugo mortality (M_h)	3,080,966	918,303	161,893	333,279	640,227	1,027,264
Net growth (NG)	938,784	-675,481	49,348	635,807	369,250	559,860
Regular removals (TR_r)	3,895,865	132,220	136,555	1,150,044	1,019,350	1,457,696
Hugo removals (TR_h)	1,773,736	60,708	86,005	127,903	517,632	981,488
Net change (NC)	-4,730,817	-868,409	-173,212	-642,140	-1,167,732	-1,879,324
1990 Inventory (I_{90})	14,278,455	755,423	896,045	2,849,952	4,017,523	5,759,512

$NG = GG - M_r - M_h$

$NC = NG - TR_r - TR_h$

$I_{90} = I_{86} + NC$

Pre-Hugo inventory = $I_{86} + GG - M_r - TR_r$

Table C.10--Period change in volume of hardwood sawtimber on timberland, by component of change and ownership class, for 23 counties in South Carolina, 1986-1990

Inventory item	All ownerships	National forest	Other public	Forest industry	Farmer	Miscellaneous private
				Thousand board feet		
1986 Inventory (I_{86})	14,944,495	570,272	179,228	3,541,280	4,258,998	6,394,717
Gross growth (GG)	2,533,350	81,662	28,403	572,192	785,093	1,066,000
Regular mortality (M_r)	291,758	9,873	--	70,386	98,878	112,621
Hugo mortality (M_h)	975,019	144,847	18,178	168,079	262,298	381,617
Net growth (NG)	1,266,573	-73,058	10,225	333,727	423,917	571,762
Regular removals (TR_r)	1,794,701	78,537	12,030	553,137	399,157	751,840
Hugo removals (TR_h)	164,023	--	--	4,850	81,951	77,222
Net change (NC)	-692,151	-151,595	-1,805	-224,260	-57,191	-257,300
1990 Inventory (I_{90})	14,252,344	418,677	177,423	3,317,020	4,201,807	6,137,417

$NG = GG - M_r - M_h$

$NC = NG - TR_r - TR_h$

$I_{90} = I_{86} + NC$

Pre-Hugo inventory = $I_{86} + GG - M_r - TR_r$

Table C.11--Distribution of 1990 inventory of growing stock, by ownership class, species group, and damage class, for 23 counties in South Carolina

Ownership class	Softwoods					Hardwoods				
	1990 Inventory	Percentage of inventory in--				1990 Inventory	Percentage of inventory in--			
		Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees		Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand cubic feet	Percent				Thousand cubic feet	Percent			
National forest	196,607	55	12	22	11	149,212	40	21	20	19
Other public	254,612	70	16	8	6	87,477	64	11	11	14
Forest industry	907,363	64	19	11	6	1,010,020	70	12	7	11
Farmer	957,789	75	13	7	5	1,478,842	68	12	7	13
Miscellaneous private	1,460,727	74	11	8	7	2,081,476	70	11	7	12
All ownerships	3,777,098	71	14	9	6	4,807,027	68	12	8	12

Table C.12--Distribution of 1990 inventory of sawtimber, by ownership class, species group, and damage class, for 23 counties in South Carolina

Ownership class	Softwoods					Hardwoods				
	1990 Inventory	Percentage of inventory in--				1990 Inventory	Percentage of inventory in--			
		Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees		Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand board feet	Percent				Thousand board feet	Percent			
National forest	755,423	58	12	20	10	418,677	36	20	18	26
Other public	896,045	70	17	7	6	177,423	43	20	16	21
Forest industry	2,849,952	66	19	8	7	3,317,020	64	15	8	13
Farmer	4,017,523	75	13	7	5	4,201,807	64	12	8	16
Miscellaneous private	5,759,512	73	13	7	7	6,137,417	63	12	8	17
All ownerships	14,278,455	72	14	8	6	14,252,344	63	13	8	16

Table C.13--Change in volume of softwood growing stock on timberland, by diameter class, for 23 counties in South Carolina, 1986-1990

Diameter class (inches at breast height)	1986 Inventory	Net change	1990 Inventory	1990 inventory in--			
				Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand cubic feet			Percent			
5.0-6.9	429,755	-65,092	364,663	68	13	13	6
7.0-8.9	636,017	-53,320	582,697	71	12	12	5
9.0-10.9	750,921	-138,543	612,378	73	14	8	5
11.0-12.9	768,374	-227,552	540,822	72	14	6	8
13.0-14.9	670,699	-151,324	519,375	72	14	7	7
15.0-16.9	546,665	-154,674	391,991	72	15	7	6
17.0-18.9	390,308	-99,269	291,039	69	15	9	7
19.0-20.9	255,152	-63,967	191,185	74	13	7	6
21.0 and larger	367,215	-84,267	282,948	66	17	11	6
All classes	4,815,106	-1,038,008	3,777,098	71	14	9	6

Table C.14--Change in volume of hardwood growing stock on timberland, by diameter class, for 23 counties in South Carolina, 1986-1990

Diameter class (inches at breast height)	1986 Inventory	Net change	1990 Inventory	1990 inventory in--			
				Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand cubic feet			Percent			
5.0-6.9	473,665	-26,509	447,156	78	8	7	7
7.0-8.9	604,044	8,979	613,023	75	11	8	6
9.0-10.9	659,619	-9,128	650,491	72	11	8	9
11.0-12.9	711,364	-66,034	645,330	71	10	7	12
13.0-14.9	642,148	-6,502	635,646	73	11	6	10
15.0-16.9	544,058	-32,429	511,629	64	14	7	15
17.0-18.9	432,505	-27,642	404,863	62	14	7	17
19.0-20.9	292,547	-10,185	282,362	60	13	9	18
21.0 and larger	642,313	-25,786	616,527	54	14	11	21
All classes	5,002,263	-195,236	4,807,027	68	12	8	12

Table C.15--Change in volume of softwood sawtimber on timberland, by diameter class, for 23 counties in South Carolina, 1986-1990

Diameter class (inches at breast height)	1986 Inventory	Net change	1990 Inventory	1990 inventory in-- Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand board feet			Percent			
9.0-10.9	2,733,479	-497,748	2,235,731	74	13	8	5
11.0-12.9	3,480,059	-1,024,486	2,455,573	72	14	6	8
13.0-14.9	3,446,844	-781,009	2,665,835	72	14	7	7
15.0-16.9	3,052,743	-861,508	2,191,235	72	15	7	6
17.0-18.9	2,318,662	-597,629	1,721,033	69	15	9	7
19.0-20.9	1,576,250	-401,458	1,174,792	74	13	7	6
21.0 and larger	2,401,235	-566,979	1,834,256	66	17	11	6
All classes	19,009,272	-4,730,817	14,278,455	72	14	8	6

Table C.16--Change in volume of hardwood sawtimber on timberland, by diameter class, for 23 counties in South Carolina, 1986-1990

Diameter class (inches at breast height)	1986 Inventory	Net change	1990 Inventory	1990 inventory in-- Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand board feet			Percent			
11.0-12.9	2,453,516	-214,030	2,239,486	70	10	7	13
13.0-14.9	2,603,726	-11,132	2,592,594	72	12	6	10
15.0-16.9	2,478,661	-138,623	2,340,038	64	14	7	15
17.0-18.9	2,124,710	-131,826	1,992,884	62	14	7	17
19.0-20.9	1,536,842	-56,647	1,480,195	59	13	9	19
21.0 and larger	3,747,040	-139,893	3,607,147	53	14	11	22
All classes	14,944,495	-692,151	14,252,344	63	13	8	16

Table C.17--Change in volume of softwood growing stock on timberland, by species, for 23 counties in South Carolina, 1986-1990

Species	1986 Inventory	Net change	1990 Inventory	1990 inventory in-- Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand cubic feet			Percent			
Longleaf pine	451,329	-148,690	302,639	80	8	6	6
Slash pine	195,053	-49,239	145,814	68	19	7	6
Shortleaf pine	244,145	-39,025	205,120	85	7	3	5
Loblolly pine	3,173,218	-684,412	2,488,806	69	15	10	6
Pond pine	277,260	-97,505	179,755	59	15	16	10
Virginia pine	54,852	-2,940	51,912	79	4	2	15
Pitch pine	--	--	--	--	--	--	--
Table Mountain pine	--	--	--	--	--	--	--
Spruce pine	15,678	-2,298	13,380	67	17	3	13
Sand pine	--	--	--	--	--	--	--
Eastern white pine	--	--	--	--	--	--	--
Eastern hemlock	--	--	--	--	--	--	--
Spruce and fir	--	--	--	--	--	--	--
Baldcypress	295,328	-11,304	284,024	77	13	5	5
Pondcypress	74,169	-2,458	71,711	76	13	8	3
Cedars	34,074	-137	33,937	90	2	1	7
All species	4,815,106	-1,038,008	3,777,098	71	14	9	6

Table C.18--Change in volume of hardwood growing stock on timberland, by species, for 23 counties in South Carolina, 1986-1990

Species	1986 Inventory	Net change	1990 Inventory	1990 inventory in--			
				Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand cubic feet			Percent			
Select white oaks	272,297	-4,575	267,722	71	11	4	14
Select red oaks	92,266	-9,072	83,194	63	10	5	22
Chestnut oak	--	--	--	--	--	--	--
Other white oaks	159,951	-8,096	151,855	65	10	11	14
Other red oaks	997,617	-68,770	928,847	58	12	9	21
Hickory	162,474	-12,027	150,447	69	6	8	17
Yellow birch	--	--	--	--	--	--	--
Hard maple	1,524	253	1,777	100	--	--	--
Soft maple	379,354	8,598	387,952	58	12	13	17
Beech	7,159	-81	7,078	66	--	19	15
Sweetgum	1,094,447	-44,362	1,050,085	71	14	7	8
Tupelo and blackgum	1,152,982	-19,399	1,133,583	78	11	6	5
Ash	168,598	-11,422	157,176	64	13	10	13
Cottonwood	34,812	-2,114	32,698	70	15	11	4
Basswood	275	58	333	--	--	100	--
Yellow-poplar	246,737	-11,649	235,088	60	13	8	19
Bay and magnolia	16,306	1,091	17,397	85	--	5	10
Black cherry	9,649	194	9,843	76	4	9	11
Black walnut	3,179	290	3,469	70	19	11	--
Sycamore	26,500	-6,049	20,451	74	6	4	16
Black locust	--	--	--	--	--	--	--
Elm	90,972	-3,530	87,442	77	11	4	8
Other eastern hardwoods	85,164	-4,574	80,590	75	6	7	12
All species	5,002,263	-195,236	4,807,027	68	12	8	12

Table C.19--Change in volume of softwood sawtimber on timberland, by species, for 23 counties in South Carolina, 1986-1990

Species	1986 Inventory	Net change	1990 Inventory	1990 inventory in-- Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand board feet			Percent			
Longleaf pine	1,971,710	-683,707	1,288,003	80	9	4	7
Slash pine	476,183	-133,231	342,952	74	15	3	8
Shortleaf pine	644,400	-135,583	508,817	84	7	1	8
Loblolly pine	12,939,294	-3,327,718	9,611,576	69	16	9	6
Pond pine	1,095,182	-399,830	695,352	59	13	15	13
Virginia pine	142,686	2,082	144,768	80	2	2	16
Pitch pine	--	--	--	--	--	--	--
Table Mountain pine	--	--	--	--	--	--	--
Spruce pine	85,748	-15,586	70,162	69	18	--	13
Sand pine	--	--	--	--	--	--	--
Eastern white pine	--	--	--	--	--	--	--
Eastern hemlock	--	--	--	--	--	--	--
Spruce and fir	--	--	--	--	--	--	--
Baldcypress	1,342,624	-33,448	1,309,176	76	14	5	5
Pondcypress	256,991	1,363	258,354	76	14	7	3
Cedars	54,454	-5,159	49,295	84	6	--	10
All species	19,009,272	-4,730,817	14,278,455	72	14	8	6

Table C.20--Change in volume of hardwood sawtimber on timberland, by species, for 23 counties in South Carolina, 1986-1990

Species	1986 Inventory	Net change	1990 Inventory	1990 inventory in--			
				Healthy trees	Class 3 trees	Class 2 trees	Class 1 trees
	Thousand board feet			Percent			
Select white oaks	829,475	-32,877	796,598	64	12	5	19
Select red oaks	349,767	-31,137	318,630	54	12	5	29
Chestnut oak	--	--	--	--	--	--	--
Other white oaks	505,941	-23,157	482,784	56	12	13	19
Other red oaks	3,142,149	-306,073	2,836,076	49	13	10	28
Hickory	504,622	-91,285	413,337	58	8	8	26
Yellow birch	--	--	--	--	--	--	--
Hard maple	1,981	497	2,478	100	--	--	--
Soft maple	824,432	-18,253	806,179	45	14	16	25
Beech	16,393	333	16,726	50	--	24	26
Sweetgum	3,067,063	-97,404	2,969,659	66	16	8	10
Tupelo and blackgum	3,586,932	6,144	3,593,076	77	12	6	5
Ash	471,183	-14,355	456,828	62	13	10	15
Cottonwood	136,056	305	136,361	69	18	10	3
Basswood	--	--	--	--	--	--	--
Yellow-poplar	914,192	-35,830	878,362	57	14	8	21
Bay and magnolia	15,565	584	16,149	71	--	10	19
Black cherry	6,437	-1,445	4,992	100	--	--	--
Black walnut	5,699	1,707	7,406	64	36	--	--
Sycamore	114,364	-28,433	85,931	75	--	4	21
Black locust	--	--	--	--	--	--	--
Elm	202,674	-10,621	192,053	69	13	6	12
Other eastern hardwoods	249,570	-10,851	238,719	73	6	5	16
All species	14,944,495	-692,151	14,252,344	63	13	8	16

Table C.21--Area of timberland, by ownership class, hurricane damage status, and previous stand type, for 23 counties in South Carolina

Ownership class and damage status	All stand types	Previous stand type				
		Pine plantation	Natural pine	Oak-pine	Upland hardwood	Lowland hardwood
				Acres		
Public						
No damage	112,503	26,721	51,762	12,895	10,667	10,458
Damaged	420,358	59,767	198,063	51,472	21,627	89,429
Total	532,861	86,488	249,825	64,367	32,294	99,887
Forest industry						
No damage	516,688	266,733	76,771	50,316	38,532	84,336
Damaged	1,092,775	449,281	166,864	79,131	68,046	329,453
Total	1,609,463	716,014	243,635	129,447	106,578	413,789
Nonindustrial private						
No damage	1,398,047	168,493	392,336	223,836	305,259	308,123
Damaged	2,995,604	237,671	887,980	414,759	545,058	910,136
Total	4,393,651	406,164	1,280,316	638,595	850,317	1,218,259
All ownerships						
No damage	2,027,238	461,947	520,869	287,047	354,458	402,917
Damaged	4,508,737	746,719	1,252,907	545,362	634,731	1,329,018
Total	6,535,975	1,208,666	1,773,776	832,409	989,189	1,731,935

Table C.22--Area of timberland, by broad management class and pre- and post-Hugo stocking percentage for manageable stand trees, for 23 counties in South Carolina

Broad management class and pre-Hugo stocking (percent)	All classes	Post-Hugo stocking (percent)								
		0-14	15-29	30-39	40-49	50-59	60-69	70-84	85-99	100+
					Acres					
Pine plantations										
0-14	50,543	50,543								
15-29	25,410	7,156	18,254							
30-39	15,305	--	--	15,305						
40-49	51,701	14,180	--	2,460	35,061					
50-59	54,082	9,807	12,947	7,607	2,336	21,385				
60-69	65,571	7,107	--	--	5,042	12,995	40,427			
70-84	177,808	14,534	7,955	18,665	22,167	10,352	14,423	89,712		
85-99	170,663	10,536	9,751	--	4,640	7,798	7,377	30,046	100,515	
100+	597,583	30,045	10,321	18,711	14,375	15,191	22,341	48,520	45,899	392,180
All classes	1,208,666	143,908	59,228	62,748	83,621	67,721	84,568	168,278	146,414	392,180
Natural pine										
0-14	395,308	395,308								
15-29	114,515	23,044	91,471							
30-39	104,214	14,936	9,803	79,475						
40-49	106,979	16,695	27,854	2,418	60,012					
50-59	159,892	30,020	16,804	21,605	21,631	69,832				
60-69	191,813	18,759	12,836	9,044	15,221	16,763	119,190			
70-84	254,364	44,771	12,012	16,622	20,774	7,494	39,407	113,284		
85-99	238,761	37,569	3,503	13,128	15,037	2,418	24,431	37,748	104,927	
100+	207,930	38,169	23,536	9,987	2,459	12,836	4,792	12,820	16,369	86,962
All classes	1,773,776	619,271	197,819	152,279	135,134	109,343	187,820	163,852	121,296	86,962
Oak-pine										
0-14	229,089	229,089								
15-29	99,555	14,036	85,519							
30-39	68,267	9,517	7,127	51,623						
40-49	76,258	9,378	2,460	24,072	40,348					
50-59	90,742	14,427	--	14,777	11,818	49,720				
60-69	64,006	4,465	16,716	6,989	7,493	4,635	23,708			
70-84	107,087	7,343	4,582	6,909	7,395	7,228	23,262	50,368		
85-99	53,347	--	--	2,396	8,280	2,259	11,106	5,903	23,403	
100+	44,058	4,696	4,506	2,679	2,396	4,582	--	6,978	7,513	10,708
All classes	832,409	292,951	120,910	109,445	77,730	68,424	58,076	63,249	30,916	10,708
Upland hardwood										
0-14	304,551	304,551								
15-29	86,758	9,461	77,297							
30-39	72,748	7,132	8,680	56,936						
40-49	84,101	8,921	9,925	2,336	62,919					
50-59	115,008	10,201	12,850	9,298	10,384	72,275				
60-69	109,474	14,278	9,686	7,282	16,904	11,248	50,076			
70-84	105,937	7,408	9,390	8,847	9,832	8,596	17,936	43,928		
85-99	65,449	2,186	--	4,847	3,639	2,478	5,469	21,000	25,830	
100+	45,163	2,336	--	--	--	--	5,076	--	2,489	35,262
All classes	989,189	366,474	127,828	89,546	103,678	94,597	78,557	64,928	28,319	35,262
Bottomland hardwood										
0-14	314,765	314,765								
15-29	103,439	30,867	72,572							
30-39	95,620	11,787	37,037	46,796						
40-49	99,121	15,036	16,799	21,388	45,898					
50-59	204,055	24,619	16,874	19,642	40,738	102,182				
60-69	198,596	11,850	24,145	30,135	27,598	50,028	54,840			
70-84	256,189	17,034	19,623	31,823	21,693	32,085	33,857	100,074		
85-99	188,591	9,517	12,268	14,327	17,595	9,415	19,813	37,191	68,465	
100+	271,559	14,237	6,996	9,774	6,996	12,329	12,231	35,754	54,436	118,806
All classes	1,731,935	449,712	206,314	173,885	160,518	206,039	120,741	173,019	122,901	118,806
All classes										
0-14	1,294,256	1,294,256								
15-29	429,677	84,564	345,113							
30-39	356,154	43,372	62,647	250,135						
40-49	418,160	64,210	57,038	52,674	244,238					
50-59	623,779	89,074	59,475	72,929	86,907	315,394				
60-69	629,460	56,459	63,383	53,450	72,258	95,669	288,241			
70-84	901,385	91,090	53,562	82,866	81,861	65,755	128,885	397,366		
85-99	716,811	59,808	25,522	34,698	49,191	24,368	68,196	131,888	323,140	
100+	1,166,293	89,483	45,359	41,151	26,226	44,938	44,440	104,072	126,706	643,918
All classes	6,535,975	1,872,316	712,099	587,903	560,681	546,124	529,762	633,326	449,846	643,918

Sheffield, Raymond M.; Thompson, Michael T. 1992. Hurricane Hugo: effects on South Carolina's forest resource. Res. Pap. SE-284. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 51 pp.

Hurricane Hugo struck South Carolina in September 1989 causing extensive mortality and damage to forest stands in 23 counties. The Forest Inventory and Analysis Work Unit at the Southeastern Forest Experiment Station conducted a special inventory of the damaged area in 1990. This Paper presents the results of that inventory and documents procedures used in the inventory and analysis. More than 4.5 million acres of timberland were significantly damaged. Volume of softwood growing stock was reduced by 21 percent with nearly one-third of the remaining volume damaged to some degree. Hardwoods sustained less immediate loss—6 percent—but one-third of the remaining hardwoods was damaged. Hurricane Hugo added more than 1 million acres to South Carolina's backlog of acreage needing regeneration.

KEYWORDS: Forest inventory, forest-damage assessments, tree-damage classifications, wind damage.

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